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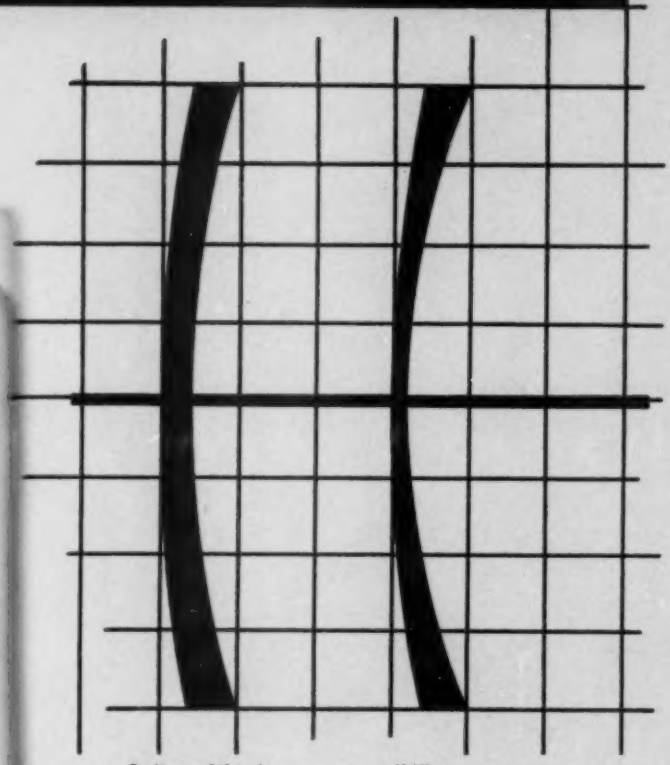

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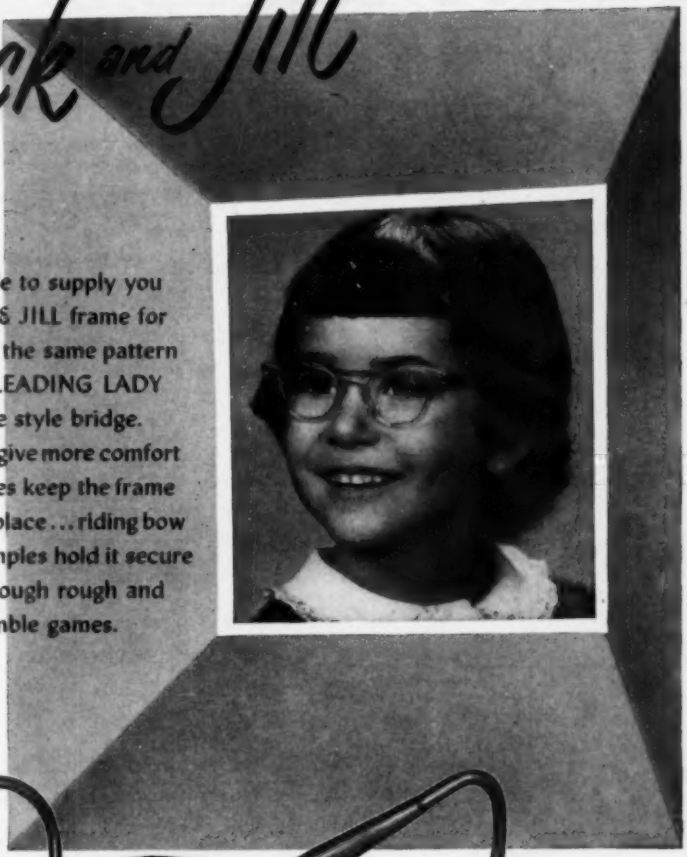

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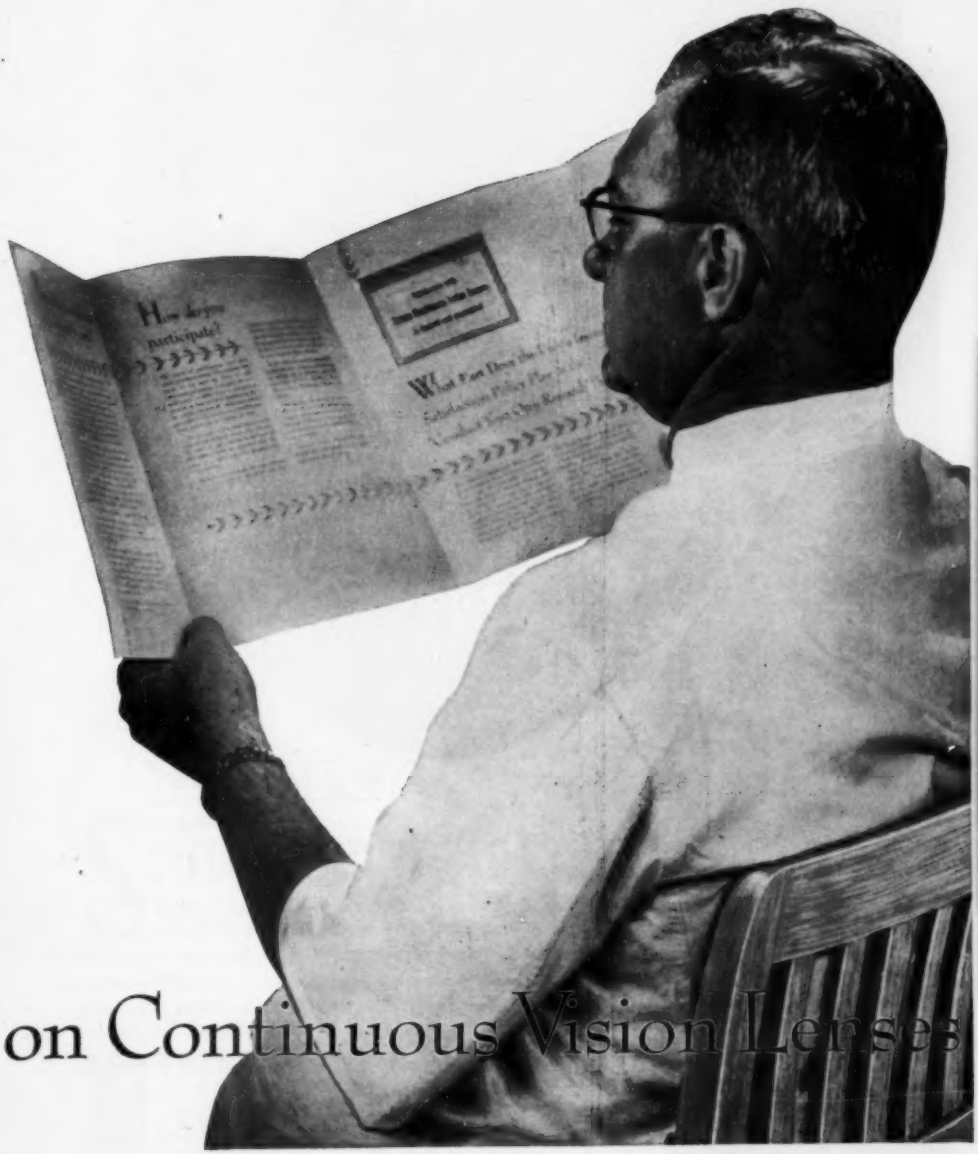

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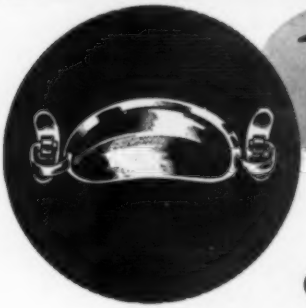

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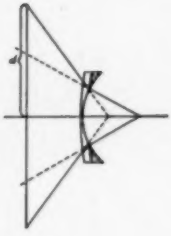

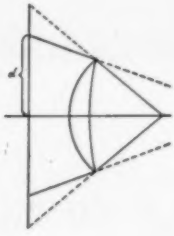

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A STUDY OF THE RELATIONSHIP BETWEEN FIXATION DISPARITY AND TARGET SIZE*

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Chicago College of Optometry
Chicago, Illinois

INTRODUCTION

One of the phenomena of binocular vision, which has been observed and described several times but which has been systematically measured only once, is that of fixation disparity (or, as it is sometimes called, retinal-slip). The paucity of observations on this subject does not mean, however, that it is an uncommon occurrence. In fact it may be observed with nearly any stereoscopic or haploscopic targets, which have identifying marks seen monocularly.

As the name implies, fixation disparity is defined as the deviation of the visual axes from any given point which is seen singly and binocularly. It is commonly assumed that during binocular fixation of any object the visual axes must intersect at one point, that point being in the plane of the object. The concept of fixation disparity denies this assumption and says rather that the visual axes may, to a limited extent, intersect either before or behind the object of regard without the sacrifice of single vision. That it is possible for the eyes to deviate from the object of regard and for the object still to be seen singly has been explained by the concept of Panum's circles.[1] In this explanation it is contended that the two retinas are associated in the cortex by means of corresponding areas rather than by discrete points. That the contention of corresponding areas is in fact true has been demonstrated consistently by studies of the horopter[2] in which it has been shown that the locus of points seen singly does not lie on a line forming the horopter but extends both nearer and farther than the line of the horop-

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The author acknowledges the faculty guidance of Dr. Z. B. Schoen and Dr. Thaddeus Murroughs.
†Optometrist. Graduate student, Chicago College of Optometry.

ter. Moreover, the extent of Panum's circles is by no means a negligible amount. According to figures referred to by Davson,[3] they cover from 5 to 26 minutes horizontally and from 3 to 4 minutes vertically.

The relationship between Panum's circles and fixation disparity has not been studied extensively. Panum's circles have to this time been employed to explain the fact that the images of an object which fall on disparate points on the retinas are not seen in diplopia when they are close to the point of fixation. In other words, physiological diplopia does not exist for points nearer or farther from the object of regard if these points are near the object. The fact that points seen stereoscopically are also seen singly even though they fall on disparate points is possible because of the existence of Panum's circles. This fact that disparate points are seen singly dominates most discussions concerning Panum's circles. Consideration of their existence, however, will show that it is not at all unlikely that they also might be used to allow the eyes to deviate from the object of regard. Thus, Panum's circles make it possible for the single vision of disparate points and, also, for fixation disparity.

In turning from the definition and explanation of fixation disparity to a consideration of the literature concerning it, it is convenient to divide the literature into two general parts. In the first will be found the reports concerning the simple observations and in the second, the systematic measurements.

As has been mentioned before, all the simple observations[4, 5, 6, 7] and reporting have been derived from the viewing of stereoscopic or haploscopic views which have identifying marks. For example, if a four spot from a deck of cards be placed on one side of a stereoscope and a five spot of the same suit on the other, very often the unified percept will show a five spot with the center spot displaced somewhat to one side.* The phenomenon can be exaggerated somewhat by the use of prisms, which put a stress on the fusional powers. The authorities cited have all used some such device to show the existence of fixation disparity though none have made any attempt to measure the amount.

The first systematic and accurate measurement of fixation disparity was a study of the effects of base-in and base-out prism.[1] The apparatus for this investigation consisted essentially of a system of polaroid projection on a wall screen, such that the subject viewed a

*A split card using this design has been made by the Keystone View Company to demonstrate fixation disparity.

total common field of 20°. In the center of this field was a small central area subtending an angle of 1.50°, in which were two small polarized vertical lines. One of these lines could be seen by one eye, and the second could be seen by the other eye. One of the lines was movable so that it could be moved horizontally into vertical alignment with the other. It can be easily understood that if the two lines were in alignment on the screen but the subject saw them horizontally separated, then fixation disparity was present. Furthermore, the distance the movable line had to be displaced gave a measure of the fixation disparity.

The procedure was to introduce lateral prism and then to measure the fixation disparity, or the change in fixation disparity, which arose from the stress placed on fusion. In order to eliminate any possible cumulative effects, the base-in and base-out prism was introduced in alternating and increasing steps. The investigators were also faced with the possibility that the subject in addition to exhibiting cumulative effects might show a tendency to align the marks by eye movements. To eliminate this problem one of the marks was presented by means of a flash, so that the subject could have no time for compensatory eye movements.

The results obtained by the procedure showed that the subjects could be divided into two categories, namely, those who showed a steady gain in fixation disparity with increasing prism power and those who had a constant limit of fixation disparity to the point of diplopia. In addition to these results, it was found that: the disparity without prisms was in the same direction as the phoria, a change in the accommodative status of the eyes by means of lenses brought a change in the disparity, and blurring by means of lenses yielded no appreciable changes in either the amount of disparity or the accuracy of the results. Finally, it was found that on increasing the size of the central target, a greater amount of fixation disparity manifested itself. This last observation is the one most pertinent to the present investigation.

STATEMENT OF PURPOSE

At the present time, much has been assumed concerning the relationship between the size of a target and the fusional process, but nothing has been done insofar as this investigator has been able to find. The general feeling seems to be, however, that there is a relationship between the size of the target and the ability of a binocular observer to see it singly.

In the investigation concerning fixation disparity and the fusional

processes[1] it was shown that fixation disparity, i.e., its presence in both quality and quantity, is in a real sense a measure of the fusional processes. This being true, the relationship between the size of the target and the fusional processes can be investigated by means of the effect of the size of the target on fixation disparity.

The question that is presented now is: What will be the change, if any, in disparity as the size of the target is changed? The best evidence at the present time for an answer to this question is that the disparity increases with the size of the target. In using lateral prism[1] the investigators found an increase in the disparity with an increase of target size. Apparently, no systematic or extensive measurements to show the nature of the relationship were performed.

Since it is possible to study the fusional processes by means of fixation disparity, the purpose of this investigation is: to determine the relationship between fixation disparity and the size of the target. The hypothesis according to the best evidence will be: that fixation disparity will increase with an increase in the size of the target.

APPARATUS

In designing the equipment for this investigation there were several requirements which needed to be satisfied. The first of these concerned the extent of the field of view. It was desired to present a total homogeneous field subtending an angle of at least 45° to the subjects. This was required to eliminate any peripheral effects. The second requirement was that of accuracy. The aim was to have a measuring device with at least 0.5′ accuracy. The next requirement was to keep the apparatus as simple as possible in order that there be a minimum of parts, and hence, a minimum possibility of bothersome aberrations and adjustments. Finally, it was essential to design the apparatus so that it could be handled easily and quickly, especially insofar as the actual measurements were concerned.

The apparatus which was built to satisfy the requirements just given consisted of three main parts, namely, the viewing instrument, the field and measuring device, and the targets.

The viewing instrument consisted essentially of two liquid reflecting prisms and a mirror. The shells of both prisms were constructed from methyl methacrylate (Plexiglas), and both were filled with petrolatum liquiduum (mineral oil). Both were 45° isosceles prisms. The faces of one of the prisms were approximately four inches square, and the other, approximately 2 inches by 4 inches. The smaller of the two had a mirror against the hypotenuse side of the prism, because,

as will be seen, the angle from which it was viewed was such that the critical angle was not exceeded in a great portion of the field. Both prisms and the mirror were mounted with their reflecting surfaces vertical on a stand in the following manner. The larger of the prisms was placed before the right eye so that the farther end of its hypotenuse face, i. e., the reflecting face, was inclined medially. The angle between an extension of the plane of the reflecting face and the median plane was 22½°. Thus, when the right eye looked into the prism, the visual axis was deviated by one reflection 45° to the left. The smaller of the prisms was placed before the left eye so that the farther end of the reflecting surface was rotated to the left. The extension of the plane of the reflecting surface intersected the median plane at an angle of 67½°. The mirror was placed immediately adjacent to the temporal edge of the ocular surface of the smaller prism and extended laterally forming an angle of 90° with the median plane. Whereas the large prism deviated the visual axis by a single reflection 45° to the left, the combination of the smaller prism and the mirror deviated the visual axis at the left eye by the same amount as that of the right, but the deviation was done by double reflection. Further, since single reflection produces lateral inversion and double reflection does not, it is possible to use one target, i. e., if it is symmetrical, instead of two as is done in a haploscope. For example, if the target is moved to the left, the right eye, which is before the inverting prism, must rotate to the right, while the left eye must rotate to the left. In this way convergence or divergence can be brought about by moving the target to the right or left, respectively. The instrument, also, allows for an independent target to be placed over a stationary target so that either may be moved while the other is stationary. This last point makes it possible to measure the fixation disparity.

Finally, it should be noted that it would be possible to obtain the same effect by the use of mirrors alone. But prisms are necessary if the field of view is to be 45°. The reflecting surface of the inverting prism must lie approximately parallel to the edge ray of the field of the right eye. Prisms increase the aperture of reflecting surfaces; consequently, one was necessary in this apparatus. The particular angles chosen were advantageous, also. If the larger prism were made to form a more acute angle with the median plane, then the prism would have had to be increased in size. If, on the other hand, the angle had been made less acute, the system before the other eye, i.e., the left in this case, would have interfered. The viewing apparatus is shown in Figure 1.

The second part of the apparatus consists of the field and measur-

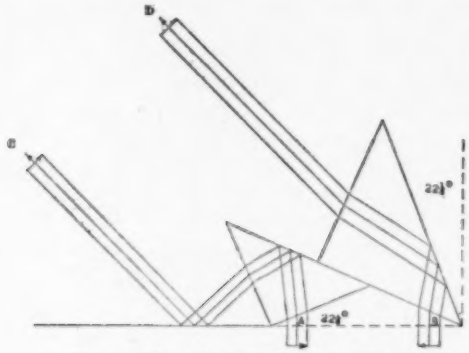

Fig. 1. Diagram of viewing apparatus.

ing device. The field was simply a standard tangent screen set at the correct height and at a distance of 1.5 meters from the viewing device. A ¾" strip of wood was secured across the screen. It was placed in a horizontal position midway between the top and bottom of the screen and was painted a flat black. This bar served a twofold purpose. First, it was used as a support for the targets, and second, it served as a target to help stabilize any vertical fusional effects. In the lower right corner of the screen was secured a meter stick, which was also horizontal—and parallel to the target support. A cursor with a vernier scale was placed on the meter stick. The vernier was such that it was accurate to 0.2 mm., i. e., the scale was 0.9 mm. long and was etched five equal divisions. Attached to the cursor was one end of a length of black nylon thread. The thread in turn extended diagonally upward and left to the upper left-hand corner of the screen, where it ran through an eye and a pulley. On the outer end of the thread a weight was attached for the purpose of keeping the thread taut as the cursor was moved along the meter stick. It can readily be seen that since the target support was secured halfway between the meter stick at the bottom and the eye at the top, the string would move horizontally half the distance as would the cursor.

When this arrangement was observed through the left prism of the viewing apparatus, the string would be seen as it actually was, i. e., running from upper left to lower right; but when observed through the inverting prism, the string appeared to extend from lower left to the upper right. The binocular view of the string was that of an "X." If the string were displaced homonymously, its two images would appear

to cross below the point of fixation, and if it were displaced heteronymously, the images would appear to cross above the point of fixation. Thus any lateral displacement in relationship to the point of fixation caused the crossing point of the images of the string to move vertically, thereby eliminating the desire for lateral alignment by compensatory eye movement. Diagram of apparatus in Figure 2.

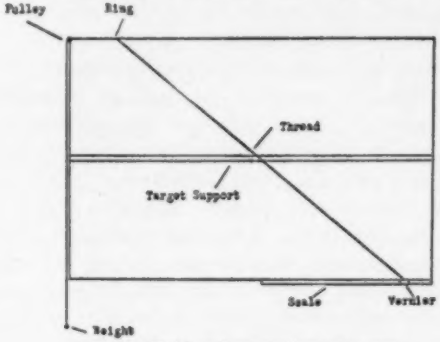

Fig. 2. Field and measuring apparatus.

The third part of the apparatus was the targets. These consisted of gray, round discs cut from poster cardboard. There were 10 of these whose diameters were such that at the distance of 1.5 meters, they subtended angles of 1°, 2°, 4°, 6°, 8°, 10°, 12°, 14°, 16°, and 18° respectively. On the backs of each were hooks which were secured along the diameter. This arrangement was convenient for attaching the targets to the target support. On the lower part of the backs of the larger targets were attached studs, which by resting against the screen held them upright. Across the front of the target a thin black line was inked. This line passed through the center of the target and was horizontal when the target was in place.

With one of the targets in place the view presented to the subject consisted of a round, gray disc, a horizontal reference line, and crossed strings. In the event that the eyes were over-converged the fixation disparity was homonymous in nature and the crossing point was below the reference line. When the cursor was moved to the right, the crossing point moved down. When the images of the string crossed at the reference line, the distance of the actual string from the center of the target gave the measure of the disparity present. The angle formed between visual and fixation axes would be that angle subtended by twice the distance between the crossing of the strings at the reference and the

center of the target. This is so for the reason that the distance the actual string is moved is seen by each eye alone. For example, if the crossing point were moved 1 cm. to the left, the left eye would see it move that amount to the left, and the right eye would see it move the same amount to the right. Since the crossing point is midway between the scale and the pulley and moves one-half the distance of the cursor, the distance between the intersections of the visual axes at the target is the same as the distance the cursor is moved.

There are three criticisms to be stated concerning the apparatus. The first results from the fact that the types of reflection before the two eyes were different. Total reflection was utilized in the larger prism before the right eye while mirror reflection occurred before the left eye. This means that there was slightly more light transmitted to the right eye than there was to the left. The effect was not noticeable, however, much less disturbing. The second criticism arises from the occurrence of retinal rivalry between the images of strings at their crossing point. The effect of this rivalry was disturbing at times, but the accuracy of the judgments was not reduced as will be seen later. A final criticism which might be raised is that the construction of the viewing instrument increased the pupillary distance approximately 60 mm. Since the string was immediately adjacent to the targets, the parallax introduced by the increased pupillary distance was negligible.

PROCEDURE

The procedure was divided into two parts, namely, the test for the reliability of the instrumentation and the measurement of fixation disparity with the different sizes of targets. Both series of findings were performed with the apparatus set so that there was no prismatic effect at the working distance of 1.5 meters. To do this the viewing instrument was rotated 45° to the right, because its construction is such that both visual axes are deviated 45° to the left. Two sets of vertical reference lines were constructed from short, straight wires, each pair mounted with a separation equal to the investigator's pupillary distance. One set (A and B in Figure 1) was placed on the viewing instrument, one (A) before the center of the aperture for the left eye and the other (B) before the center of the right aperture. The other set (C and D, Figure 1) was placed on the target support. The reference marks on the support were then moved right and/or left until the two right reference marks and the two left reference marks were aligned at the same time. The investigator stood back approximately 2 meters and aligned the two right marks with his right eye and without moving

his head used the left eye to align the left marks. Now when the two sets of reference marks were removed, the visual axes of a subject, if parallel, intersected the field with a separation equal to the pupillary distance. Since the left eye was the one which followed any motion on the field directly, the target was placed with its center at the point where the right reference point (D) was. The right eye then converged to the target the same amount as it would have with no viewing apparatus present. In other words, the eyes were now converged to a point 1.5 meters away. If the target had been placed any other place, the eyes would have to rotate opposite to each other, and a prismatic effect would have resulted. For example, a target placed to the left of D (Figure 1) would cause the left eye to rotate right, but the right eye would have to rotate to the right also. A target to the right of D would cause over-convergence of both eyes.

In order to make the setting of the target quicker and easier, a projector was used to project a reference line coinciding with point D. Then by turning on the projector it was simple to set the target correctly in place.

The first part of the procedure was to check the reliability of the apparatus. To do this one target (4°) and one observer were used. The apparatus was adjusted, and the observer was seated before the viewing instrument. First the cursor was moved to the extreme right and then moved left until the images of strings crossed at the reference line of the target. Then the cursor was moved to the extreme left and moved back to the right until the images of the string again crossed at the reference line. This procedure was repeated 40 times. Then the findings of every other setting from the right were averaged, and the remaining settings from the right were also averaged. Then the two averages were compared to determine the consistency of the results. The same was done with the findings found by moving the cursor from the left until the images crossed at the reference line.

To measure the amount of fixation disparity relative to the size of target, groups of six, four, and five subjects were taken at a time and measurements were made in a room illuminated under daylight conditions. The specific procedure was to take two findings, one from the right and one from the left, with each of the targets. Starting with the 1° target the zero reading of the scale was taken by aligning the thread with the center of the target. Settings were determined for each of the group of subjects. Next, the 2° target was put in place and the procedure was repeated. Finally, the rest of the targets were put in place in succession, and settings were made as before. After the three groups

had been tested, the results were analyzed to determine the effect of size on fixation disparity.* To determine the fixation disparity the zero setting on the scale was subtracted from the scale reading taken when the two images crossed at the reference line of the target. Finally, in order to make sure that the instrument remained in adjustment the setting was rechecked after the measurements with each target in place had been completed.

RESULTS

The results of the first part of the investigation, which was concerned with the determination of the reliability of the measurements taken with the instrumentation, are shown in Table I. It will be seen that the averages of the alternate settings taken from the right were 64.21 cm. and 64.19 cm. The difference between the two is 0.02 cm., which at 1.5 meters is 24″ in angular terms. Similarly, the alternate averages of the settings taken from the left show a difference of 0.03 cm. or 41″. These results show that the instrumentation gave reliable results.

TABLE I
TEST FOR ACCURACY
Data obtained from one subject on a 4′ target (in cm.)

Trials	R_1	L_1	R_2	L_2
1	64.20	63.86	64.66	63.86
2	64.20	63.98	64.58	63.70
3	64.10	64.00	64.26	63.60
4	64.08	63.60	63.90	64.16
5	63.92	63.90	64.40	64.22
6	64.12	63.84	64.00	63.84
7	64.20	63.96	64.16	63.80
8	64.14	63.78	64.10	63.98
9	64.06	63.72	63.70	63.74
10	64.12	63.88	64.16	63.88
Total	642.14	638.52	641.92	638.78
Average	64.21	63.85	64.19	63.88

Difference between R_1 and R_2 = 0.02 cm.
Difference between L_1 and L_2 = 0.03 cm.

Table II gives the raw data obtained from the measurements of fixation disparity using the targets of different sizes. The sizes of the targets represented by the numbering system are given in Table III.

An examination of the data presented in Table II before statistical evaluation shows two things. The first of these is that under the conditions of the experiment the findings which indicated over-convergence

*The original intention was to run 50 subjects through the tests as described above, but the results, as will be seen, indicated that 15 subjects were sufficient.

TABLE II

TABULATION OF RAW DATA (recorded in .1 mm.)

Subject	Target 1		Target 2		Target 3		Target 4		Target 5		Target 6		Target 7		Target 8		Target 9		Target 10	
	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L	R	L
1	78	48	34	6	54	0	40	—96	50	20	8	—22	24	—12	30	0	38	30	50	42
2	54	20	12	—6	48	34	28	—14	28	0	—12	—38	6	6	14	8	—40	—54	—18	—26
3	32	—2	38	20	36	22	38	14	58	64	40	—8	76	6	54	20	58	38	38	4
4	—6	28	38	20	116	38	126	114	86	72	68	44	128	122	154	120	142	26	102	98
5	74	38	90	116	122	52	104	68	128	70	132	82	134	114	150	120	188	166	154	262
6	30	4	82	—42	70	32	118	66	98	60	84	62	106	24	116	50	166	114	142	112
7	88	70	0	—6	18	—16	38	30	56	30	26	—110	—46	—70	—74	—108	4	—40	—46	—86
8	54	28	74	14	42	—12	46	12	64	16	26	14	24	—20	24	—46	16	—12	12	—36
9	92	38	46	20	46	—20	50	6	132	58	26	30	44	—8	44	14	54	2	66	—24
10	36	—6	44	—6	22	—42	—2	54	38	4	—12	—84	—14	—114	—74	—138	—14	—74	—68	—166
11	44	54	22	—4	46	2	60	4	64	—10	150	—12	70	58	86	50	62	20	90	52
12	124	34	—14	—46	—6	—110	58	—72	40	0	36	—80	—28	—228	—68	—268	6	—58	66	—186
13	362	234	122	14	112	196	80	88	82	72	126	120	136	104	114	108	138	142	174	160
14	22	—18	38	34	18	—22	62	32	40	46	88	50	48	24	22	4	58	48	10	—22
15	40	66	30	2	0	—24	18	—4	20	18	58	74	40	34	32	36	66	—20	50	100

TABLE III

Number	Target Size
1	1°
2	2°
3	4°
4	6°
5	8°
6	10°
7	12°
8	14°
9	16°
10	18°

greatly exceed those of under-convergence. In other words, the scale reading was in most cases to the right of the zero setting as is indicated by the positive findings. This meant that the image seen by the left eye crossed the reference line to the right of the center of the target and the image seen by the right eye was to the left of center when the images were judged to be crossing at the reference line. This being true, the eyes were over-converged in the great majority of the cases. The reasons for the over-convergence are not to be explained as a part of this investigation since they do not lie within the confines of its purpose. It can be said, however, that there is a good possibility that the attention required for the judgments by the subjects could have been the cause.

The second observation which can be made concerning the raw data is that the findings for any single subject show a more or less random distribution through all 10 of the targets. That is to say, there can be found no tendency for the fixation disparity to increase with the size of the target. These findings might just as well have been taken with one target as with the 10 which were used.

A comparison of the average findings of the 10 targets reveals that there is indeed no relationship between the fixation disparity. This is revealed in the following table:

TABLE IV

Size of Target	Average Fixation Disparity at 1.5 meters (in 1/10 mm.)
1°	59
2°	26
4°	29
6°	39
8°	50
10°	32
12°	26
14°	20
16°	42
18°	37

The disparity had its highest value with the 1° target. Its value dropped immediately, increased to the 8° target, decreased to the 14° target, increased on the 16° target, and finally decreased on the 18° target. Although inspection reveals that no correlation exists, the actual correlation was worked out by the product-moment method where the size of the target in degrees is the X function and the fixation disparity in 0.1 mm. is the Y function.

	X	Y	XY	X^2	Y^2
	1	59	59	1	3481
	2	26	52	4	676
	4	29	116	16	841
	6	39	234	36	1521
	8	50	400	64	2500
	10	32	320	100	1024
	12	26	312	144	676
	14	20	280	196	400
	16	42	672	256	1764
	18	37	666	324	1369
Sum	91	360	3111	1141	14252

$$r = \frac{XY - NM_xM_y}{\sqrt{(X^2 - NM_x^2)\ (Y^2 - NM_y^2)}}$$

$$= \frac{3111 - (10)\ (9.1)\ (36)}{\sqrt{(1141 - 828.1)\ (14252 - 12960)}}$$

$$r = \frac{-165}{635}$$

$$r = -.26$$

Since the data are limited to a value of 10 for N, the coefficient of correlation is not significant. A coefficient of 0.632 would be needed for a significant correlation at the 5% level; therefore, the —0.26 found falls far below the required value.

While the purpose of the investigation was to study the effects of the size of the target on fixation disparity, it is interesting to call attention to a few other observations. The mean of all the samples, for example, is 3.6 mm. in the direction of over-convergence, which in angular measurement amounts to 8′. The total range of findings was from 82′ of over-convergence to 62′ of under-convergence.

CONCLUSIONS

The results of this investigation yield two main conclusions:

1. The first conclusion is that the test for the reliability showed the instrumentation to be satisfactory for the purpose of the experiment.
2. The second conclusion is that under the conditions of the experiment, the hypothesis which was postulated was disproved. There was no relationship whatsoever revealed between fixation disparity and the size of the target, much less a direct one.

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ERRATA

In the July, 1951, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY, in the article, "An Investigation of Voluntary as Distinguished From Reflex Accommodations," by Dr. Elwin Marg, School of Optometry, University of California, Berkeley, California, the author informs us that the last sentence in the second paragraph on page 355, should be changed to read as follows:

"Two subjects (R. H. and C. L.) had symptoms with *attempted* positive voluntary accommodation which indicates that accommodative asthenopia may be of central rather than peripheral origin."

* * *

On page 360 of Dr. William P. Schumann's paper, "One Hundred Years of the Ophthalmoscope—Von Helmholtz, the Man, His Life and Work," the beginning of the fifth paragraph should read, "In 1848 through his friend, Bruecke, Helmholtz was made teacher of anatomy," instead of "In 1948." Also, in error, Figure 3 was reversed.

A FACTOR ANALYSIS OF VISION TESTS*

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Industries, as well as the ophthalmic professions, which give vision tests usually assume that each test used measures a unique visual skill. Consequently a battery of several tests is thereby assumed to measure specifically each of several traits of vision. The validity of this rationale was the subject of the present investigation.

The study involved the analysis of test results obtained from one commercially available instrument, the Bausch and Lomb ortho-rater[5] now being widely used for industrial vision testing. By statistical methods, such as multiple factor analysis, a battery of tests can be grouped into factors or clusters. The ortho-rater has been carefully constructed to make each of the visual tests included in the battery as accurate, reliable, and valid as conveniently possible. Some early investigations were conducted by Giese[8], Jobe[5], Tiffin[10], Tiffin and Kuhn[12], Tiffin and Wirt[13], Wirt[14], and others. To a considerable extent these studies have been made with respect to the validity of the phorias, acuities, and other tests as selection devices.

The ortho-rater was developed by joint research of the Division of Education and Applied Psychology of Purdue University and the Scientific Bureau of the Bausch and Lomb Optical Company. Its development represented a significant step in the solution of problems of industrial visual requirements for jobs. As a result of this initial research, 12 visual performance tests were selected and incorporated into a single instrument that was designed by the engineering staff of Bausch and Lomb. The tests are administered to industrial employees, and the resulting test scores, along with pertinent personnel data, are sent to the Occupational Research Center of the Division of Education and Applied Psychology, Purdue University, where they are tabulated and

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*Submitted on October 16, 1950, for publication in the August, 1951, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
This article is based on the author's dissertation entitled "A Factor Analysis of Vision Tests" submitted to the faculty of Purdue University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June, 1949. The dissertation was directed by Dr. Joseph Tiffin, Director of the Division of Education and Applied Psychology, Purdue University.
†Ph.D.

analyzed. The work of Tiffin[11] and Wirt[14] explains in detail the methodology used in this research center.

The usefulness of the phoria tests for classification and placement has been shown by Tiffin[10]. The studies of McCormick[7] and Carr[1] demonstrate that certain profile formulas can be used for groups of jobs, particularly if they are divided into families of near jobs and families of a combination of near and far jobs. The near jobs included predominantly near-vision jobs—those which require close, and rather constant, visual attention within a relatively restricted range, usually within arm's reach. The near and far jobs were those requiring varying degrees of both near and far visual attention. These families of jobs have profile patterns that indicate the "cutoff" points which correspond best with success on the job as measured by various criteria. An indication of the interrelationship of visual acuity at different distances was found by Giese[3]. The differences he obtained between near and far acuity were similar to those secured by Tiffin and Wirt[13]. A comprehensive survey of visual requirements for a wide variety of jobs has been published by Tiffin[11].

Although all of these studies indicate that each phase of the problem of vision is important, there has been no comprehensive analysis to show empirically or statistically how many factors or clusters are now included in the battery of test scores obtained on the ortho-rater.

In an analysis of various acuity and phoria measurements with commercial screening devices as compared with clinical methods, Cook[2] used the ortho-rater as one instrument. With the exception of near vertical and far lateral phoria measurements, which he found to be specific to the ortho-rater, the other tests included in the battery measure the same functions as are measured by other screening devices used by the Navy.

STATEMENT OF THE PROBLEM

The original investigation was designed to isolate the group and specific factors which are operating in the current battery. A secondary problem which arose early in the research was to devise a new method of scoring the phorias so that rectilinear correlations could be used. Isolating the group and specific factors that operate in this particular battery had never been done. Thus it was thought to be entirely possible that the emphasis on making near and far profile patterns different from each other might have been too great. Also, it might be that the difference in the left eye and right eye scores had been over emphasized and that a test of both eyes could replace either or both of these. It

was thus imperative to discover the particular factors which were operating. After these had been isolated, it was important to indicate their contributions to the intercorrelations as shown by their factor loadings. It was felt that a factor analysis might result in a more accurate naming of the fundamental factors accounting for the variance of the 12 visual skills secured.

The importance of the second problem, that of devising a new scoring method for the phorias, was recognized early in the investigation. On the vertical phorias a low score indicated *left hyperphoria* while a high score showed *right hyperphoria*. On the lateral phorias a low score denoted *esophoria* while a high score denoted *exophoria*. The middle scores in both cases indicated *orthophoria*. The work of Carr[1] demonstrated curvilinear relations between phoria and other visual skills. He found that the phoria scores tend to decrease on both extremes and to be high in the central portion (orthophoria) when plotted against criteria of job success on various jobs. Since orthophoria was considered to be the "best" score, it was to be expected that this would be true. There has been some question as to whether or not the two extremes of these scales were actually measuring the same thing in larger or smaller quantities, or whether it might be that over-convergence (esophoria) is an entirely different function than under-convergence (exophoria).

PROCEDURE

Source of data. The data were obtained from the files of the Occupational Research Center. The test scores for 2,000 individuals were taken in random order from the 100,000 sets of scores now available. This sample involved employees from over 50 companies. Within each company a wide variety of jobs was used. Care was taken to avoid selection of employees with any reference to standing on the continuum of job success. The individuals were a heterogenous group. There was no selection with regard to sex which resulted in an approximately equal number of men and women.

Scoring the phorias. As stated previously there was a definite need to re-score the phoria tests to modify the curvilinear relationship that existed between phorias and other measures of visual skill.

With the assistance of Professor I. W. Burr, of the statistical department of Purdue University, a new scoring key was devised. This key extended the four phoria tests into eight tests. These were named:

1. Far vertical left hyperphoria.
2. Far vertical right hyperphoria.
3. Far lateral esophoria.
4. Far lateral exophoria.

5. Near vertical left hyperphoria.
6. Near vertical right hyperphoria.
7. Near lateral esophoria.
8. Near lateral exophoria.

The scoring was similar to that of the former keys but used different starting points. In the original scoring of the vertical phoria the range had been from 1 to 9. In the new key the scores of 5 and 6 were designated *orthophoria* and scored as 0. The scores of 1 to 4 were *left hyperphoria* but the scoring was now in reversed order, i. e., 4 became 1, 3 became 2, etc. In like manner 7 through 9 were re-scored as *right hyperphoria* with 7 as 1, 8 as 2, and 9 as 3. In both of these new keys from the opposite end of the continuum through orthophoria a score of zero was given.

The lateral phorias were scored in a comparable manner, with 7 as *orthophoria*, 1 through 6 as *esophoria*, and 8-15 as *exophoria*.

Visual tests. The usual 12 tests of the ortho-rater as described by Jobe[5] were changed to 16 by increasing the number of phoria tests as stated above. Table 1 gives a list of the tests used and the range of possible scores obtainable on each.

TABLE 1
LIST OF TESTS IN THE BATTERY AND RANGE OF OBTAINABLE SCORES

Test	Range
1. Far Vertical Left Hyperphoria	0- 4
2. Far Vertical Right Hyperphoria	0- 3
3. Far Lateral Esophoria	0- 6
4. Far Lateral Exophoria	0- 8
5. Near Vertical Left Hyperphoria	0- 3
6. Near Vertical Right Hyperphoria	0- 4
7. Near Lateral Esophoria	0- 4
8. Near Lateral Exophoria	0- 9
9. Far Acuity—Both Eyes	1-15
10. Far Acuity—Right Eye	1-15
11. Far Acuity—Left Eye	1-15
12. Depth	0- 9
13. Color	0- 6
14. Near Acuity—Both Eyes	1-15
15. Near Acuity—Right Eye	1-15
16. Near Acuity—Left Eye	1-15

Method Used. The basic methodology used was factor analysis, which also had been used in a previous study by Cook[2]. Multiple factor analysis is a branch of statistical method concerned with the resolution of a set of descriptive variables in terms of a small number of factors. The raw data of factor analysis are correlation coefficients between measurements taken two at a time. Factor analysis attempts to explain each of these correlation coefficients by means of a number of factors

or underlying bases of association smaller than the number of original measurements. The factors isolated are of two varieties, group and specific.

Once isolated by factor analysis, the factors are adjusted to determine whether or not they conform to an hypothesis or theory previously postulated. When the analysis is complete, it is then possible to determine the factors operating in the battery. It is also possible to show the amount each test taps the factor by a factor loading. A factor loading represents the correlation between a given measurement and one of the factors found. It may be positive or negative in sign depending on the nature of its relationship with the particular measurement involved.

Factor loadings do not exactly reproduce the correlation coefficients upon which they are based due to chance errors in the correlation coefficients themselves because of test unreliability. The difference between the sum of the cross products of the factor loadings for any two tests and their actual correlation coefficients is called a residual. Inspection of the residuals enables one to evaluate the thoroughness and effectiveness of the factor analysis and/or the purity or spuriousness of the original correlations. When the analysis is complete the residuals should be scattered symmetrically about zero and their range and variability should be as small as possible.

The name to be attributed to a factor which has been isolated is a matter of "scientific judgment" rather than a problem in statistics. The name is based on the tests that have high loadings on that factor and describes that characteristic which apparently caused the intercorrelations of the tests involved. If the loadings reproduce the original correlations fairly accurately, they can be said to be mathematically accurate; but the naming of the factors may still be questioned because of arbitrariness in the rotation of the axes.

In the current study the hypothesis postulated is that a subject's battery of test scores may be thought of as comprised of several different factors each of which involves one or more of the individual tests used in the battery.

PRESENTATION AND DISCUSSION OF RESULTS

Intercorrelations. Table 2 shows the original product moment correlation coefficients of the tests as used in the first matrix. The number of the sample was 2,000 for most of the tests, but on one it fell as low as 1,927. The range of the absolute *r*'s was rather great, from .01 to .73.

TABLE 2
ORIGINAL INTERCORRELATIONS OF THE SIXTEEN TESTS OBTAINED FROM THE ORTHO-RATER

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Far Vertical Left Hyperphoria															
2. Far Vertical Right Hyperphoria	—.171														
3. Far Lateral Esophoria	+.146	+.226													
4. Far Lateral Exophoria	+.026	—.053	—.403												
5. Near Vertical Left Hyperphoria	+.336	+.014	+.045	+.086											
6. Near Vertical Right Hyperphoria	+.017	+.436	+.114	—.006	—.151										
7. Near Lateral Esophoria	+.162	+.183	+.344	—.089	+.109	+.160									
8. Near Lateral Exophoria	+.018	+.005	—.168	+.310	+.140	+.069	—.275								
9. Far Acuity—Both Eyes	—.122	—.128	—.174	+.089	—.070	—.158	—.084	—.037							
10. Far Acuity—Right Eye	—.125	—.086	—.166	+.076	—.109	—.124	—.079	—.049	+.702						
11. Far Acuity—Left Eye	—.123	—.131	—.158	+.088	—.075	—.178	—.108	—.032	+.718	+.574					
12. Depth	—.124	—.110	—.137	+.034	—.037	—.145	—.085	+.034	+.421	+.424	+.438				
13. Color	—.073	—.101	—.152	+.083	—.046	—.099	—.065	+.033	+.297	+.286	+.287	+.246			
14. Near Acuity—Both Eyes	—.124	—.158	—.095	+.051	—.157	—.186	—.138	—.075	+.573	+.507	+.530	+.316	+.253		
15. Near Acuity—Right Eye	—.115	—.120	—.122	+.054	—.153	—.162	—.125	—.071	+.498	+.617	+.438	+.301	+.286	+.696	
16. Near Acuity—Left Eye	—.018	—.159	+.196	+.066	—.015	—.198	+.221	—.059	+.491	+.398	+.699	+.336	+.292	+.719	+.586

Residuals. After the fifth factor was removed the largest residual was .17 with a mean or average residual of .03 and a root mean square of .04.

Factors. The factors with their loadings are listed in Table 3. This table shows the factors after they have been rotated. The first and second factors were rotated and the factors again plotted, but no further rotation seemed to cause a greater number of loadings to become positive or to maximize the loadings.

TABLE 3
FACTOR LOADINGS AFTER ROTATION

	Factor Loadings					
	I	II	III	IV	V	h^{2*}
1. Far Vertical Left Hyperphoria	—.130	—.245	—.257	.435	—.226	.383
2. Far Vertical Right Hyperphoria	—.260	—.370	.445	—.282	—.189	.518
3. Far Lateral Esophoria	—.060	—.640	—.184	—.142	.129	.484
4. Far Lateral Exophoria	.245	.465	.093	.122	—.464	.515
5. Near Vertical Left Hyperphoria	.020	—.180	—.119	.473	—.256	.336
6. Near Vertical Right Hyperphoria	—.200	—.280	.437	—.253	—.272	.447
7. Near Lateral Esophoria	—.020	—.595	—.079	—.011	—.101	.371
8. Near Lateral Exophoria	—.070	.295	.158	.150	—.315	.239
9. Far Acuity—Both Eyes	.795	.065	.219	.181	.125	.733
10. Far Acuity—Right Eye	.750	.070	.221	.097	.097	.635
11. Far Acuity—Left Eye	.800	.050	.163	.147	.111	.703
12. Depth	.510	.140	.101	.084	.090	.305
13. Color	.390	.160	—.005	—.006	—.059	.181
14. Near Acuity—Both Eyes	.790	.090	—.192	—.203	—.096	.719
15. Near Acuity—Right Eye	.765	.050	—.154	.202	—.107	.664
16. Near Acuity—Left Eye	.780	—.200	—.310	—.089	—.174	.783

*Communalities

These rotated factors were then squared to show the total variance attributed to each factor, with the sum of these squares expressed as communality (h_k^2). This communality is called "common-factor variance" by Thurstone[9]. Table 4 shows for each test the proportion of total variance attributed to each factor (column h_k^2), to a specific factor (column k_s^2), and the error variance (column k_e^2). To get the error variance for a test it is necessary to know the reliability of the test. The reliabilities used were those obtained from an unpublished study of test-retest scores obtained on a group of 371 workers in the Bausch and Lomb Optical Company. The error variance is unity minus the reliability of the test.

When the communality and error variance of a test are known it is possible to identify the specific factor in the test. The communality

subtracted from unity give the uniqueness of the test. This specificity is a combination of error variance and the specific factor. Thus the specific factor is the specificity minus the error variance. Guilford[4] (p. 477) gives the derivation of the formulae that are needed to derive the specific factors once the communality and reliabilities are known.

It is noteworthy that the communalities of the tests vary from .181 for *color* to .783 for *near acuity—left eye*. Also of interest are the three tests, *color*, *depth*, and *near lateral esophoria* which are highly loaded in specific factors. Two of these have their heaviest loading in Factor I while the third had its heaviest loading in Factor V which was the last factor extracted.

Naming the factors. In this study the naming of the factors was not a major problem since the loadings of the specific tests were rather definite. After consultation with Professors Burr, Lawshe, and Tiffin the

TABLE 4

PROPORTION OF TOTAL VARIANCE ATTRIBUTED BY FACTORS I THROUGH V, SPECIFIC FACTORS, AND ERROR VARIANCE FOR EACH TEST

	Proportion of Total Variance of Respective Tests Attributed by							
	Factor I k_1^2	Factor II k_2^2	Factor III k_3^2	Factor IV k_4^2	Factor V k_5^2	Communality h_k^2	Specific Factor k_s^2	Error Variance k_e^2
1. Far Vertical Left Hyperphoria	.017	.060	.066	.189	.051	.383	.451	.166
2. Far Vertical Right Hyperphoria	.068	.140	.198	.080	.032	.518	.232	.250
3. Far Lateral Esophoria	.004	.410	.034	.020	.016	.484	—.002	.518
4. Far Lateral Exophoria	.060	.216	.009	.015	.215	.515	.207	.278
5. Near Vertical Left Hyperphoria	.000	.032	.014	.224	.066	.336	.439	.225
6. Near Vertical Right Hyperphoria	.040	.078	.191	.064	.074	.447	.241	.312
7. Near Lateral Esophoria	.000	.354	.006	.000	.011	.371	.445	.184
8. Near Lateral Exophoria	.005	.087	.025	.023	.099	.239	.603	.158
9. Far Acuity—Both Eyes	.632	.004	.048	.033	.016	.733	.082	.185
10. Far Acuity—Right Eye	.563	.005	.049	.009	.009	.635	.230	.135
11. Far Acuity—Left Eye	.640	.003	.026	.022	.012	.703	.162	.135
12. Depth	.260	.020	.010	.007	.008	.305	.525	.170
13. Color	.152	.026	.000	.000	.003	.181	.604	.215
14. Near Acuity—Both Eyes	.624	.008	.037	.041	.009	.719	.041	.240
15. Near Acuity—Right Eye	.585	.002	.024	.041	.012	.664	.131	.205
16. Near Acuity—Left Eye	.609	.040	.096	.008	.030	.783	.012	.205

"scientific judgments" made in naming these factors were:

Factor I. Acuity. The first factor contained a large portion of the loading for the entire battery. The tests most heavily weighted in this factor were all of the *far* and *near* acuities as well as *color* and *depth*. Since in an industrial situation one might expect the employee to have the major weaknesses of both far and near vision partially corrected, these would probably not be distant factors. The fact that *color* and *depth*, as measured by the ortho-rater, were included in this factor leads one to believe that both may be dependent upon good acuity. Also, in multiple factor analysis, if one test measures a distinct factor and no other test measures it, the characteristic measured by that test will not appear as a factor no matter how strong. Thus this characteristic has to be treated as a specific factor rather than as a group factor. In Table 4 one will note that in the variance for specific factor both *color* and *depth* had unusually high loadings, (.604 and .525, respectively).

Factor II. Esophoria. The high weightings of test 3 and test 7, *far lateral esophoria* and *near lateral esophoria*, made the name of this factor almost self-evident, the factor evidently being one of esophoria (near and far). The fact that there was no definite break between far and near tests is noteworthy.

Factor III. Right Hyperphoria. The high positive loadings in test 2 and test 6, *far vertical right hyperphoria* and *near vertical right hyperphoria*, definitely indicated that this was a vertical phoria factor. In this instance it was a specific portion of the vertical phoria continuum, that of right hyperphoria.

Factor IV. Left Hyperphoria. Test 1 on *far vertical left hyperphoria* and test 5 on *near vertical left hyperphoria* are both heavily loaded. Here again there was no distinction between far and near tests.

Factor V. Exophoria. The more factors extracted the smaller were the remaining residuals. The loadings on tests 4 and 8 were much lower than those of the first few factors, but they do indicate rather definitely an exophoria factor.

Comparison with other studies. Cook's[2] study of various screening devices reports some data with which the results of this study can be compared. His first intercorrelations were similar to those secured here. Cook's far binocular acuity correlated with near binocular acuity .52 as compared with .573 (Table 2) in the present study. Far binocular acuity and depth correlated .40 in his study and .421 in this one. Near binocular acuity and depth showed a correlation of .22 and .316 respectively for the two studies. The intercorrelations found for

the phorias were again quite similar.

After the factors were extracted, the residuals were very much alike in both studies. The most interesting aspect of the comparison between the studies, however, was the final factor loadings obtained. As far as they are comparable, the factor loadings were heavily weighted on the same tests. The factor Cook named *retinal resolution* could be compared with *Factor I* of this study which was named *acuity*. In this factor, for far binocular acuity Cook obtained a loading of .77 as contrasted to .795 (Table 3) in this study, and on depth he found a loading of .46 versus a loading of .510 obtained here. The two lateral phoria factors isolated in this study—Factors II and V—compare favorably with the single factor he obtained. He isolated a far, as well as a near, lateral phoria factor which this study did not indicate. The vertical phoria loading on the factor which Cook named *Vertical Phoria* was found by him to be .51. Two vertical phoria factors were revealed by the present study—Factors III and IV. The near right hyperphoria test had a loading of .437 on Factor III and the near left hyperphoria test a loading of .473 on Factor IV. It is possible that if Cook's scores on phorias had been divided he might have obtained these other factors also. Since no factor was found to indicate a distinction between near and far tests in the ortho-rater, the other devices used in Cook's study may have precipitated this factor in his study.

CONCLUSIONS AND RECOMMENDATIONS

A factor analysis was made with a random sample of 2,000 ortho-rater test scores from approximately 100,000 sets of scores now available at the Purdue Occupational Research Center. The following conclusions were made:

1. A subject's battery of test scores may be accounted for by a smaller number of group factors than the number of original tests. From the battery of 16 tests, five group factors were derived and subsequently designated as: I. Acuity. II. Esophoria (Lateral). III. Right Hyperphoria (Vertical). IV. Left Hyperphoria (Vertical). V. Exophoria (Lateral). *Color* and *depth* were isolated as specific factors.

The results of the present study thus show that seven factors—five group and two specific—are involved in the 12 original ortho-rater tests.

2. The method of scoring the phorias usually used was found to produce a strong curvilinear relationship which could not be adequately expressed by the Pearsonian *r*. It was, therefore, necessary in this study to develop a new method of scoring the phorias. The tech-

nique devised and utilized consisted of dividing the current key into two portions using the deviations in score units from orthophoria as the phoria scores. When it is necessary to obtain correlations it is recommended that this technique be used. When the ortho-rater is used in its standard industrial setting which involves visual skill profiles for various jobs and job families, it is, of course, unnecessary and not even desirable to use this new method of scoring the phoria tests.

3. Another recommendation formulated as a consequence of the present study is that it be followed with a study of the scores obtained with the ortho-rater using partial and multiple correlation. If it is possible for high scores in certain of the vision tests to compensate for low scores in other tests a multiple correlation would show how the various vision tests in the ortho-rater are related to job success. It is possible that the use of the Wherry-Doolittle Test Selection Method may prove productive of additional contributions to the understanding and application of the ortho-rater as an industrial tool. The Beta weights for each test and the resultant multiple regression equation, combined with empirically determined cut-off scores for any tests on which the original relationships obtained showed that job success seldom or never occurs among people scoring below a certain score, might make the prediction of job success from vision scores more effective than methods presently in use. It is suggested that several factors be considered in such a study, namely, grouping the jobs into families, dividing the employees by age groups, and perhaps making a comparison by sex.

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BOOK NOTICES

RECENT ADVANCES IN OCULAR PROSTHESIS. J. H. Prince. Published by the William & Wilkins Company, Baltimore, Maryland. 150 pages. Cloth. $4. 1950.

This volume is intended to augment the author's previous book, "Ocular Prosthesis," which was published a few years ago when the use of plastic artificial eyes was still in the testing period. The author, after working and investigating in several countries (England, Australia, New Zealand, America and Canada), reports the results of increased experience and improved methods of manufacture of plastic prostheses which he believes will soon supersede glass prostheses.

The first chapter describes the technique for making conjunctival impressions and their use for making molds for custom plastic artificial eyes.

The Meshed Implant Technique is reviewed in Chapter II and many helpful illustrations accompany the text. Besides the fitting techniques, several operative techniques are described.

Chapters III, IV and V are devoted to "Unusual Cases": "Plastic Surgery" and "Patient Posture."

The properties of Methyl Methacrylate and the preparation of artificial irides are discussed in Chapters VI and VII.

The final three chapters are concerned with the personal preparation by the practitioner of some of the materials used in the making of ocular prostheses, the fabrication of acrylic eyes and the processing of artificial eyes on a large scale. The processes and equipment described are invariably completed by excellent diagrams and photographs.

This book has much to recommend it to the ophthalmic surgeon, to the fitters of artificial eyes, and to anyone interested in up-to-date knowledge on ocular prosthesis.

ROBERT E. BANNON

POST-OPERATIVE ORTHOPTIC CARE IN A CASE OF RIGHT CONVERGENT SQUINT WITH AMBLYOPIA AND NYSTAGMUS*

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CASE HISTORY

S. B., age 4½ years. Has been cross-eyed since birth, the result of instrument delivery, reported to be radical. Child's head was badly bruised and out of shape from use of instruments. Numerous visits to eye doctors resulted in waiting until the child was older. At age 4 (January, 1948), had surgery on right eye to correct the right convergent squint. Prescription given but not worn because parents objected to glasses and the physician was not sure it would help. Mother would not bring glasses to us.

Health History: Always in good health.

Family History: No eye trouble in the family. No crossed eyes. All members in good health except father is arthritic.

Social and Recreational History: Shy and unfriendly. Does not like people of any age. Seems frightened. Does not play games. Is awkward and has very poor coordination and equilibrium.

Complaints: Parents complain "Child does not seem to see well and eyes do not work together. Turns head to right when she tries to look at an object. Stumbles and falls and tips things over at the table."

PRELIMINARY FINDINGS

External Examination: Lids and conjunctiva, good color and no injection. Marked nystagmus, lateral, monocular and binocular.

Motility: Rotations, right, left and both: jerky; unpredictable. Excursions: monocularly: unrestricted. Binocularly: right does not go templeward beyond the midline.

Pupillary Reactions: Pupils: right, left and both: normal to both light and accommodation. Pupils very large at all times.

OPHTHALMOSCOPIC EXAMINATION

All media clear. Disc of good color and well defined. Normal ratio and appearance of veins and arteries. Fundus: good color: no exudates or other evidence of pathology.

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ANALYTICAL EXAMINATION

May 4, 1948: Practically impossible to do any kind of testing. Child cried and was very uncooperative. All of the findings reported were made after many attempts, and not all on this first visit!

Visual Skills: (poor cooperation)

Visual acuity: R. about 30%. L. about 60%. No binocular vision. Rarely, even with occlusion, was right eye brought in at this point. Vertical imbalance: noted in all tests. Hand and eye coordination very poor.

Observations: Child is shy, irritable, uncooperative; cries easily. Appears to expect criticism, reprimand and rebuff. "Sidles" into the training room. Afraid of the technician and instruments. Very awkward. Runs into furniture. Holds chin up very high; tilts head back and to the left.

Retinoscopy: Static: approximately + 2.00 O.U.

DIAGNOSIS

The eye surgeon had made a diagnosis of "Common crossed eye, with no complications. Right convergent 25Δ." Our diagnosis was "Post-operative convergent squint, with vertical involvement, right. Bilateral amblyopia and nystagmus. Serious psychological and coordination aspects."

TREATMENT

Office training was given three times a week, for an hour each session, when possible, from May 20, 1948 to September 16, 1948: 47 hours in all.

Procedures used between May 20 and June 15: Retinal rivalry: very slow to change eyes: much "black-out" especially of right eye. Rotations: monocular: very jerky, and irregular. Hand coordination exercise: could not use both hands simultaneously. No rhythm or coordination. Lange coordinator: reported seeing both red and blue—separated. Rotoscope and troposcope: for simultaneous perception: sometimes *seemed* to superimpose targets.

Home training: complete body coordination exercise was prescribed: ball rolling; ball bouncing, etc.

Progress report: After 15 hours of training: Still does not work well. Head tilt continues. Rotations: slight improvement, monocularly. Hand coordination: some improvement. Analytical: still cannot get cooperation to do any part. Skills: simultaneous vision sometimes. Evidence of vertical involvement. Fusion: none. Acuity: R. apparently slight improvement. L. no change. Advised to continue home and office training. Parents cooperative.

Procedures: June 17, 1948 to September 16, 1948.

Coordination training continued at home. Advised to patch eyes alternately about two hours daily, at meals and games. Lange coordinator: color slides: sometimes colors moved slightly. Sometimes stayed still. Reported colors crossed. Rotations: monocular: improved. Troposcope: for fusion: sometimes seemed to fuse. Hand Coordination: good improvement. Fixation training: Tel-eye-trainer, Rotor # 3 (slow) calesthenics cards and moving pictures, and using hand motion, pointing in direction of arrows, poor. Form recognition: Flashmeter: monocularly: very slow to respond, and uncertain even when pictures of familiar objects were used.

Progress report: At the completion of 47 hours of office training, we are still unable to make a visual anaysis which could be considered in any degree adequate. The findings which were made are: Visual acuity: Snellen chart: R. 20/50; L. 20/50. Static retinoscopy: R. + 2.25; L. + 1.50. Distance phoria: about 14 esophoria. Dissociated cross cylinder: R. + 2.75; L. + 2.75. Induced phoria: omit.

Skills: Now has simultaneous perception, but with definite vertical involvement. Fusion: has second degree, far and near. Definite esophoria trend with vertical manifested. Nystagmus continues about the same. Patch has not been worn! Some small improvement was noted in the findings, but much improvement in general behavior and attitude. Child has started to kindergarten. Will discontinue training for one month.

November 9, 1948 to August 11, 1949. Trained periodically: 65 hours total. Examination: Skills: Simultaneous perception, but still with vertical. Lateral imbalance, far and near: much esophoria 2nd degree fusion: far and near: passed, but with vertical displacement. Visual acuity, DB test: R. 50%; L. 60%. Observations: Attitude and interest much improved.

Procedures: Continued same procedures, working for improvement of basic skills and coordination, and for improved body posture. Some procedures were added: Vectoluminator, with broken field polaroid and viewers were used for tracing with pointer. Tachistoscope, for form recognition and drawing the form: January—(oral report—good. drawing—very poor.) February—form reproduction—good. May—forms—good, numbers—good, but reversed them. Home work: advised to continue patching alternately. Continue body coordination exercises.

Observations: *April, 1949:* Attitude and work much better. Mother reports that when eye turns in, it does not turn very much. "Chin up" posture almost completely gone. No fumbling during meals. No stumbling and falling. Now is able to run like other children. Great

personality improvement. *July, 1949:* On Brock rings: no float; no size change, but does have lateral movement. Hand coordination much better. Coloring better. *August, 1949:* Can superimpose Brock rings. Head tilt alternates: sometimes right, sometimes left. On Cheiroscope: can project numbers on AN 2.

Vacation was given from August 11 to October 24, 1949. Body coordination training to continue at home during vacation.

October 24, 1949 to December 1, 1949. Mother reports great improvement during vacation from training. School reports visual acuity on Snellen chart: R. 20/30; L. 20/50. Is having hand, eye, ear coordination training in school. Teacher says she is not yet ready to read. Examination: Visual acuity: no change. Pupils: medium size. Head tilt: to right. Lange: part superimposition of red and blue. Fixations: poor. Nystagmus persists. Summary of Murroughs tests: manifests poorly adapted. Anomalous projector, with progress toward normal retinal correspondence. Observations: Much improvement in posture and body coordination. Hand coordination—very good.

Procedures: Continue working for better general coordination, using troposcope, rotoscope, Brock rings, Lange coordinator, for better fusion range and acuity. All work to be binocular.

SUMMARY

No prescription has been used throughout the training. The mother is now willing to allow us to use lenses if necessary. Home training has been continuous. Practically no patching has been accomplished, because of the serious psychological situation it created.

The nystagmus persists, although it has slowed down. The acuity is still subnormal and lenses do not improve it. Binocular posturing of eyes is markedly improved. Some vertical deviation is measurable. Head and body posture are much improved. Motor responses and orientation in space is much better, as evidence in walking, running, etc.

Much improvement is evidenced in general performance of tasks given in training, although findings do not reflect it.

The greatest improvement is in posture—both eyes and body—and in behavior and personality. A shy, unhappy, awkward, cross-eyed child has become a happy, social, graceful, attractive and achieving girl.

Recommendations: Training must be continued periodically for some time, and lenses—for help in holding the gains made, probably will be prescribed.

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VISUAL CORRECTION AND SCHOOL ACHIEVEMENT*

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In the Fall of 1949 all boys in the Colorado State Industrial School were given a standard achievement test—the California Progressive Achievement Test. At the same time the Otis Mental Ability Test was administered. These tests were a part of a battery of educational and psychological tests administered to all boys upon their admittance to the school.

At the same time in cooperation with the Colorado Optometric Association, a visual survey was performed at the industrial school.‡ Each boy was tested with the battery of vision tests incorporated in the ortho-rater.§ These test results were sent to the Occupational Research Center, Purdue University, for analysis. The Occupational Research Center has studied a large number of vision tests administered to school children.[1] From an analysis of these test data, a minimum visual standard for school work has been constructed in a manner similar to the method by which minimum visual standards for industrial jobs have been established.[2] The test scores obtained from the students in the Boys' Industrial School were compared to this standard and those boys whose visual skill scores were below the requirements of the standard were identified.

From the total number of boys thus identified two groups were determined. These groups were matched on the basis of I. Q. and grade placement at the time of the initial testing. The first group, composed of 25 subjects, was given a clinical examination and suitable corrective lenses were prescribed. The second group, composed of 27 subjects, was also given a clinical examination and the need for eye care was established clinically but no correction was prescribed. At the end of the fall term (approximately four months later) both groups

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§The ortho-rater is a visual testing device manufactured by the Bausch and Lomb Optical Company for the visual classification and placement of industrial employees.

were retested with the same educational achievement and intelligence tests as were administered at the beginning of the period. The change in the educational achievement of the two groups was then examined. The results are shown in Table I.

TABLE I

Differences between the group with visual correction and the group without visual correction.

Measure	Group without Correction	Group with Correction	Difference	Standard Error	t-ratio
Mean I. Q.	79.84	84.37	4.53	4.29	1.06
Mean initial grade placement	5.70	5.64	.06	.51	.12
Mean gain in grade placement	.62	1.21	.59	.12	4.92**

**Significant at the .01 per cent level.

It will be seen from Table I that the matching of the two groups on the basis of intelligence test results was quite close. The difference being 4.53 with a standard error of the difference of 4.29 and t ratio of 1.06. These data would indicate that there is no significant difference in the average Otis test score of the two groups.

Simliarly, it will be seen from Table I that the matching on the basis of initial grade placement was also very close. The difference in mean grade placement of the two groups was .06 with a standard error of the difference of .51 and a t ratio of .12. These data would also indicate that there was no significant difference in the grade placement of these two groups at the time of the initial testing.

During the experimental period that group which received corrective lenses showed an average gain in grade placement of 1.21 grade levels. During the same period the group which did not receive corrective lenses showed a mean gain in grade placement of .62 grade levels. This represents a difference in favor of the group receiving corrective lenses of .59 grade levels with a standard error of the difference of .12 and a t ratio of 4.92. These data would indicate a significantly greater gain for that group which received corrective lenses.

It would appear from these data that among children whose visual skills are below the minimum level required for school work, those who receive professional assistance for their visual problems show a greater gain in educational achievement than do similar children who do not receive such professional aid. This in turn would suggest that at least a certain proportion of low school achievement may be due to the existence of visual problems which can be alleviated by professional eye care.

It should be pointed out that the present study represents a more highly controlled experimental situation than that which is possible in the ordinary public school situation. In the Boys' Industrial School, not only is the educational system standardized for all of the subjects in both groups since they are all attending the same school system, but the environment outside of the school hours is also controlled for both groups. In the normal public school situation groups such as those compared in the present study may be placed in more than one school unit within the community and thus the educational environment may not be similar. More important, the environment experienced by subjects in the two groups in those hours of the day when they are not in the school is completely uncontrolled. There is no way to insure that both groups receive the same out-of-school experiences and we can only attempt in a very rough way to measure what these out-of-school experiences might have been. Any attempt to estimate the effect of differences in the outside environment must be extremely rough and unsatisfactory. In the present study, all members of both groups are in an environment which is controlled for 24 hours of the day. Not only the in-school environment but out-of-school environment as well is markedly standardized and is equated for the two groups. It would therefore seem that the results obtained in the present study could be ascribed to the experimental variable (visual correction) with much more certainty than is true in the case of studies in normal public school situations.

SUMMARY AND CONCLUSION

Two groups of boys resident in the Colorado Industrial School for Boys were studied. All subjects in both groups were in need of eye care as indicated by the ortho-rater battery of visual skill tests. The two groups were matched in I. Q. and educational achievement at the beginning of the study. One group was given eye care (corrective lenses) and the other was not. At the end of the experimental period (four months later) the group which had received visual correction had gained significantly more in educational achievement than had the group which received no visual correction. It is concluded that the correction of visual difficulties leads to more rapid progress in school achievement.

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THE FIRST FIVE YEARS (1914-1919) OF OPTOMETRY AT THE OHIO STATE UNIVERSITY*

Charles Sheard†
Rochester, Minnesota

It is a source of much regret that Mrs. Sheard and I shall not be present with you on the occasion of the dedication of the building to house the School of Optometry on the campus of The Ohio State University. A commitment made last fall to be a guest of honor and a speaker on the occasion of the First All Canada Congress in Optometry in Winnipeg on June 10-12 causes me to wish that some great magician would shorten, for the day, the time and space on Monday, June 11, between Columbus and Winnipeg so that I might have the great pleasure and privilege of keeping my promise to your and my Canadian friends and fellow practitioners and of being with you on this most memorable occasion. The minor hardship of any shuttling back and forth is as nothing compared to the uncertainties of air travel on a schedule which, if not possible because of weather conditions, would cause me to have failed to keep my promise and to have failed to play my part by my presence and my words for the first time in nearly 50 years and hundreds of visits and lectures both here and abroad. I am sure you would desire that I keep my record perfect.

For these reasons, then, I am unable to deliver myself in the body to you but I am delivering to you through the personage of our highly respected and much beloved professorial successor, Dr. Glenn Fry, a message of good cheer; a message of rejoicing over the great progress that has been made in optometry specifically and in the broad field of vision in general since the fourth day of August, 1914, when the course in optometry was established in The Ohio State University and I became the first professor of any such course in any university in the whole world, insofar as I know; a message of continuing interest in and support to all men and all things that are concerned educationally and professionally with vision; a message of exhortation to all of you gathered together on this momentous occasion that you and, insofar

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as such is possible, all men and women, whether they be ophthalmologists, optometrists or opticians, rededicate themselves to a continuation of reading, study, and critical examination and a greater resolve to attempt to think clearly and without confusion, as you dedicate a building to house one particular school of teaching and scientific approach to the problems of vision on that part of the campus of The Ohio State University devoted to the recently dedicated Health Center, surrounded by schools and colleges of medicine, dentistry, pharmacy and other arts and sciences pledged and consecrated to teachings, practices and researches looking toward the alleviation of suffering and pain, the eradication of disease, and the dissemination and inculcation of knowledge concerning the care of the human body—yes, if you please, the *sanctity* of the human body—that men may not only live but live the life more abundantly, with greater personal bodily and mental efficiency to better serve their fellow men to the glory of God as the embodiment of all that is good and true.

If I were with you there is so much I could say about so many persons and things in some manner or other associated with the establishment of the course in optometry as the forerunner of the creation of the school. The warmth of my heart and the evidences of my energy and drive, coupled at times with the harshness of cold logic and the biting slash of sarcasm, cannot be conveyed in proper manner and just proportions through the medium of the written word. So, of necessity, I must refrain from much indulgence in the gentle and generally profitable (it is so to me) art of reminiscing. The shorthand recording of that which follows is very sketchy and spotty, leaving many of you who are here or who may read these words on a later occasion to fill in the details.

First of all, I wish to pay tribute to the *founding fathers*. It is true that I am, from the academic or university viewpoint, the founder of the first University course. That educational undertaking could not have been accomplished without the helping hands and open pocketbooks of many men in Ohio. No man lives unto himself; no group lives unto itself; no university or part of a university lives unto itself. Any undertaking requires teamwork; a variety of necessary avenues of assistance and support. The establishment of the two year course on August 4, 1914 (changed the following year to a four year course at my request and after a series of conferences of a committee appointed by President Thompson to make recommendations) was made possible by reason of the untiring efforts of such men as Clark Sloan of Cleveland, then president of the Ohio Society; C. B. Edgar of Cleveland;

C. N. McDonnell, P. C. Harris, Dan Hubbell and Homer White of Columbus; F. P. Barr of Lancaster; John Eberhardt of Dayton and Emil Klein of Cincinnati. Of course, there are other names that should be mentioned and if I have failed to include them I am asking that I be pardoned for such sins of omission, for I am writing these words at the midnight hour and into the early morning hours and have no access to exact references at the moment.

I also wish to pay tribute to the *first class* of 10 young men. I can call them by name, I can see each of their faces, I can remember the many conversations of one kind and another and concerning one matter and another which we had together—for this was the humble beginning of a very important educational movement and there were many questions and queries, nay even dire accusations, unfriendly comments, destructive criticism. Yes, indeed: a young professor setting out on an uncharted and unknown course, he himself setting the course and guiding himself and the 10 fine young chaps by the light of the star as he saw it, the courage of his convictions, and his bulldog tenacity. And if, as the years have come and gone, I have moved on into other and broader fields of education and research, and have become more liberal and broader in my viewpoints and contacts with the result that the "ism" and the "ology" have become wholly of secondary importance and the search for and acquisition of the truth insofar as such is possible has become paramount and supreme, let it be remembered that I owe a debt of inexpressible gratitude to the kindly words, warm clasp of hands and wholesome smiles of such men as Professor Landacre, professor of anatomy, and secretary of the Medical School, Dr. Judson Ferree, professor of ophthalmology, Dr. Eugene McCampbell, then appointed (1918) dean of the Medical School, Dr. Arps (later dean of the College of Education) and many others of the faculty, including my own colleagues and associates in the department of physics, not the least of whom was Dr. Alpheus W. Smith, later dean of the Graduate School.

I remember, as though it were yesterday, visiting with Professor Landacre about the work in anatomy, particularly of the eye. Said Landacre to me: "Sheard, these boys do not have more than a high school education; anatomy is a tough subject; what will happen if I have to flunk some of your 10 boys?" "Well," said I, "If you believe you should flunk them, flunk them." "Yes," said he, "then you will not have any class." "That's all right by me," said I. "I would rather see them all flunked out and have to start the whole thing over another year than to have you pass them if they are not worthy." It always

pays to stand by what is right because, in the end, that which is right and good and true will prevail. If that thesis is not correct and if weakness, incompetence, quackery, mysticism, rattle-trap doctrines and teachings are encouraged and permitted, then there is no hope. It is to wage war against such quackery, incompetence and questionable doctrines that such universities as the one in whose classic shades you now find yourselves establish such schools and build such quarters as have been dedicated today.

To return to the anatomy course and the boys: they did not fail either Professor Landacre or me, although two of them repeated some of the work. The point is: the course of instruction was sound; the professors had no favors to extend to anybody; it was a question of survival if there was anything that was fit to survive. Our belief in the goodness of the right type of education in optometry and the development of adequate service to the public based on adequacy of training was justified. The four year course—first established in The Ohio State University—did not succumb and finally became the accepted minimum standard on the part of all schools. Optometry has now come of age and may be expected to take its place as the years come and go in the body politic of the arts and sciences concerned with healing, public health and individual efficiency, commonly referred to as the field of medicine but which, in the broader concept which I have advocated and preached these many years, is the field of applied biologic science of which medicine per se is the center or the hub.

In closing I can but refer briefly to the development of clinics concerned with distinct, comfortable and efficient vision, the correlation of the functions of accommodation and convergence, and all things germane thereto. In most, if not all, instances, courses in optometry have come into the universities through the departments of physics. It was very natural that this should be the case, since the emphasis in 1914 and prior thereto was on ophthalmic optics—lenses, prisms, spectacles, frames—or the *physical* aspects. I think I can say with truthfulness and the right type of modesty that I was the first educator having anything to do with optometry who brought in and emphasized the *physiological* aspects and phases of the work and developed that which is usually referred to as dynamic ocular tests and which, in turn, have been so ably extended and amplified by Fry, Tait, Hofstetter and Morgan. Today there appears to be a tendency on the part of optometry to introduce into the solution of clinical problems of vision the *neuropsychological* or *psychiatric* aspects. Mathematics and physical science are the cornerstone or base on which all else is reared. They are the only exact sciences we have. Biology has many variables and variants and less

exactness of laws and conclusions. Psychology has still more variables and intangibles (to the point of inability to define, on occasion, with any degree of exactness) and must of necessity be the least accurate of the three, the only degree of accuracy possible being based on the other two, although the viewpoints and methods of approach differ from the physical and physiological approaches and therefore are of value. Too frequently are the contributions from the field of psychology as they relate to vision simply a jargon of words, with the use of catchy expressions and even the coinage of terms that, when carefully analyzed, mean nothing and are literally figments of the minds of the authors. The academic field of psychology and the clinical fields of abnormal psychology and psychiatry are, of necessity, somewhat nebulous and indefinite in verbiage and conclusions. It would be well for the non-medically trained practitioner to leave all of these things to the medical profession in general or, in particular, neurologists, psychiatrists and other adequately trained (with Ph.D. degrees) specialists who may be associated with them. Otherwise it is likely to resolve itself into pure and unadulterated quackery, of which I am sorry to say a considerable part of the American public seem, at the moment, to be fond and to which they are susceptible. *Optometry has a sphere of real service and usefulness and has enough to do if it will attend to its own practices which have been built on solid principles over these past 50 years.*

The faculty of The Ohio State University and the many acquaintances and friends in the city of Columbus, Ohio, will always be close to my heart. I came to them as a cub instructor (the bottom of the list) in physics in 1907. In the Spring of 1908 I went to Cedar Point to address a state meeting of optometrists and opticians. This was the beginning of the making of acquaintances and friendships which led, through devious pathways and sundry means, to the beginnings of an educational adventure which finds its culmination, in part at least and for the day and age in which we live, in the establishment of a school of optometry and a home in which to house it in dignity and with honor on the applied biological and health sciences campus of The Ohio State University.

May the dedication of this building to the arts and sciences concerned with vision also carry with it a rededication of ourselves to the support of that which is true and good and lovely beyond all comparison. May God bless us and keep us and cause His face to shine upon us, giving us health and strength to labor on, and kindness and wisdom as we serve those who come to us for assistance and counsel, exemplifying at all times the spirit of the Golden Rule. This is the sincere wish and heart's desire of your friend Charles Sheard.

PRACTICAL LIGHTING*

Bruce Jensen†
Newark, New Jersey

Through your chairman, Dr. J. R. Wittekind,‡ several of the country's outstanding lighting scientists, Dr. W. M. Gilbert,[1] Mr. H. L. Logan,[2] Dr. S. Hibben,[3] and Dr. M. Luckiesh,[4] have presented technical papers. However, there comes a time and a place when scientific principles must be applied in a practical way.

This is not done, usually, by the scientists. Who, then, does apply lighting practically to the everyday problem? The lead is taken today largely by the utility companies who do this primarily because of their immediate contact with commercial and industrial establishments in their respective territories. Of course, there is the matter of additional revenue in which the utilities are interested, but they are interested also in improved vision of workers, increased production, and in the general well-being of the people within the territory served.

Utilities generally accomplish the practical aspects of lighting by means of lighting specifications, usually prepared for customers on a gratis basis. In addition, the lamp companies, manufacturers' representatives, jobbers' men, and electrical contractors also apply practical lighting at the customer level.

In this presentation, I will confine myself to industrial and office lighting, since it is in these fields that the seeing tasks are most severe, and it is the employees of offices and industrial establishments who must rely upon eye specialists for assistance in securing better vision through corrective measures applied to the eye.

First, let us review industrial lighting, which is a most important production tool. It can result in improved products, lower numbers of rejects, reduced accidents and improved employee morale. These benefits are gained, however, only if the important tool, lighting, is used correctly. Every type of industrial work presents its own particular problem. The seeing task must be analyzed by a practical lighting engineer. It may be that the work being done is on a horizontal plane, on a vertical plane, or a combination of the two, and it may be rough, medium, fine, continuous, or intermittent. It may be done on a glossy

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surface, on a semi-glossy surface, or on a dull or dark surface. There is no such thing as an all-purpose industrial lighting plan. Each problem must be approached as an individual one, and a practical solution must be secured.

There are three elements needed for sight: light, the object to be seen, and the eye.

To illustrate, in a dark room we may have eyes and objects and yet, for lack of light, be unable to see these objects.

I would like to discuss more fully one of the factors needed in seeing the object. In this connection, there are four things that have a bearing upon seeing, assuming, of course, that you have the light and the eye to accompany the object to be seen. These are:

(1) *Time.* It requires time to see. As we all know, the seeing process is one of fixation, movement, fixation, movement, and so on. Each fixation represents a time element that must enable the light from the object to reach the eye in sufficient quantity to stimulate the proper nerve centers in the brain. The time required for seeing can be reduced by having a sufficient quantity of light on the seeing task. A simple experiment to illustrate this is through the use of a camera, the back of which has been removed. Place your eyes in the position of the film and snap the shutter. You will find it impossible to read the type on a newspaper, for example, held in front of the camera. If the camera is set for a time exposure, however, with the lens remaining open for a period of time, it is possible to read some of the words.

(2) *Size.* The size of an object is dependent upon the visual angle subtended by the eye, and in most of our seeing tasks, it is impossible for us to change the size of the object on which we are working. For instance, a watchmaker must work with tiny wheels and pinions, whereas a worker in a turbine foundry is working consistently with large pieces of equipment which also cannot be changed in size. However, light on any object has a faculty of apparently magnifying it, since more light is reflected to the eye which seems to increase the size of the angle.

(3) *Brightness.* The brightness of an object depends upon the light reflected from it to the eye. This is measured in foot-lamberts or, in European countries, as reflected footcandles. I think it is easily evident that, depending upon the finish of the object, it is capable of reflecting a large portion of the light falling upon it or of absorbing most of it. In industry and in office work, there are many opportunities for changing the brightness of an object in a practical way through altering its surface, and the practical lighting engineer makes wide use of this method.

(4) *Contrast.* Still referring to the object, it is possible to see it better if there is contrast between it and its immediate background or surroundings. For example, white thread on a black cloth provides excellent contrast, whereas white thread on white cloth provides almost none and results in a difficult seeing task. By means of light, the practical lighting engineer can increase the contrast between an object and its background, and great use is made of this method in the lighting field.

There are other factors which enter into the solution of any lighting problem. They are:

(1) *Direct glare,* which is the light seen by looking directly at the sun, for example, or an exposed electric lamp.

(2) *Reflected glare,* which results when light strikes a specular surface and is reflected unpleasantly to the eye.

(3) *Shadows,* which also enter the lighting problem; harsh shadows which are annoying, and occasional useful shadows which supply depth to certain pieces of equipment being viewed.

Control of the various factors entering into the seeing problem is part of the task of the practical lighting engineer. Speaking of artificial light sources, the direct glare problem can be handled properly through shielding with metal, glass, or plastic mediums. In conjunction with the equipment manufacturers, the lighting engineer selects a unit properly shielded for the particular seeing task involved. Reflected glare can be controlled by changing the viewing angle or the type of surface, as from specular to diffuse, and it is often possible to lighten a surface to reduce reflected glare. Also, such glare can be controlled by the use of a multitude of fixtures or fixtures of low brightness. Shadows can be minimized by controlling the direction and distribution of light falling upon the object, as well as by a multiplicity of light sources and an increase in diffusion by inserting some medium between the light sources and the object. Often, it is practical to change the mounting height of a lighting unit, lengthening or shortening the shadows, as may be desired.

The lighting tools available to us today in industry are a compromise to help us achieve comfortable lighting, bearing in mind the many factors just discussed all of which have definite effect on the seeing task. The most useful industrial lighting tool is what is commonly known as the RLM reflector. It is made of steel, finished inside with white porcelain enamel, and designed with a shielding angle from 12½ to 17 degrees. This reflector is used most widely, especially

at low and medium mounting heights. For high bays of from 30 to 100 feet, so-called high bay mounting units fill an important need and are designed to direct light downward, much as a spotlight casts its beam. A large number of local lighting units are used in industry also. These take various forms, the majority being designed for mounting on the machine directly, to provide light at specific points to increase the vision of the worker.

Modern practice has proved that established levels of illumination will be provided and good seeing conditions will result if the RLM reflector is used properly in industry. This lighting tool provides sufficient light to eliminate unfavorable contrasts. Its light distribution is such that accurate seeing can be obtained on almost any working plane, and installed in a general pattern, its utilization is such that the floor space may be used for almost any manufacturing process. This makes it possible to use an RLM layout for one type of industry and to change to another with a minimum of rearrangement of lighting units.

The usual method of planning general lighting layouts for even distribution of light with fluorescent RLM's consists of the establishment of continuous lines of units spaced to give the required intensity of light on the working plane. In some cases, individual RLM fluorescent units are mounted to form a certain pattern that may result in lines of units, rectangles, "U's," or "L's." In many industries, a localized general lighting system is found most adaptable. Such planned layouts are used where the work is semi-critical or where overhead machinery makes uniform arrangement impractical, or where production operations are reasonably permanent. In many cases, sections of a plant will be used for different purposes, such as manufacturing and storage, and then it becomes practical to use a localized general system in one area and a general system of lighting in another.

Local supplementary lighting, often called local lighting, is needed where intensities above 50 footcandles are required on the work, it being generally more practical to supply the necessary 200 or 300 footcandles by means of local units than to install a general system for that purpose. Local supplementary lighting is used largely also where the work is critical and on a vertical plane.

Any discussion of industrial lighting would not be complete without reference to lighting for inspection purposes. There are as many types of inspection lighting as there are industrial processes. However, they do fall into two general classes: non-glossy surfaces and glossy surfaces, and those requiring magnification or color matching. Today the lighting art has advanced to the point where there are available

to the lighting engineer tools to handle lighting problems that fall in either classification.

In planning lighting installations, the mounting heights of lighting units fall into three general groups:

(a) Up to 15 feet above the working plane. Units mounted at this comparatively low height must be of low brightness and equipped with proper shielding skirts. In general, such units should not be over 200 watts (filament lamps) or 40 watts (fluorescent lamps).

(b) 15 to 35 feet above the working plane. As the mounting height is raised, units of greater brightness and higher wattage lamps may be used. In this range of mounting height, 300 to 500 watt filament lamps or 100 watt fluorescent lamps may be used if properly shielded in conjunction with the mounting height.

(c) 35 feet and up. As the mounting height of a lighting unit is increased, its apparent brightness decreases, and it is possible to use units of higher brightness and correspondingly higher wattage filament and gaseous lamps. Above 35 feet, 500 to 1500 watt filament and 400 to 3000 watt mercury lamps may be used, with shielding skirts of proper design.

Maintenance is a big item in any lighting installation and if the lighting is properly designed, proper maintenance can be achieved. Included in the lighting design must be equipment planned for easy maintenance if a practical lighting installation is to result. It is entirely possible for the light output to depreciate as much as 50 per cent if the system is not properly maintained. The frequency of cleaning fixtures depends upon the area and the manufacturing processes carried on, and is determined best by periodic light meter readings. In any lighting installation, it is time to wash and clean the fixtures when the footcandles on the working plane drop from 15 to 20 per cent of the initial installed value.

In conjunction with a large part of the commerce of this country, a great deal of office work must be done. Lighting problems in offices are akin to industrial lighting problems, except that the seeing tasks are more severe and usually extend over a prolonged period of time. The lighting of large general offices has been relatively simple in that the pattern for lighting fixtures assumes somewhat the same shape as for industrial use.

In offices, however, we have a greater variety of lighting tools, since it is possible to use fixtures equipped with glass, plastic, or louvers. These elements make it possible to reduce the brightness and to control the distribution of the light better than can be done in industrial plants,

where the requirement from a breakage standpoint largely calls for steel and porcelain enamel equipment as described.

Lighting small and private offices represents the most severe problem because of the relationship between large wall area and the space involved. Furthermore, the number of work points in a small office are at a minimum and it is incumbent upon the lighting engineer to supply the necessary number of footcandles only at specific points. In office lighting, there is the matter of specular reflection, which is more severe than in most industrial areas, and to the severity of specular reflection is added the problem of the office worker usually being confined to a desk and a machine at one point, with little opportunity for moving about as does a machine operator in a plant. In offices, the lighting for a specific task can be achieved usually by study of the problem and application of the many tools available today for the purpose.

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ABSTRACTS

CONTACT LENS IN UNILATERAL APHAKIA. A. Hirtenstein. Brit. J. Ophth., 34(11), 668-674, Nov., 1950.

The author reviews briefly various views on the optical correction of unilateral aphakia when there is good vision in the other eye. It is generally agreed that the correction of unilateral aphakia by spectacle lenses is disappointing because of the aniseikonia and diplopia.

A short case history in tabular form is given of 18 consecutive patients with unilateral aphakia fitted with contact lenses over a two-year period. The routine procedure used is outlined.

Sixteen of the 18 patients had their binocular vision restored fully and were able to wear their contact lenses with comfort. Emphasis is given to the need for discrimination in selecting cases and on the value of orthoptic treatment for reeducation of binocular single vision.

R. E. B.

ALBINISM—A CASE REPORT*

J. B. Meloan†
Bushnell, Illinois

Patient: B. G., male, 4½ months.

HISTORY

"My baby was born without any pigment in his eyes," said the mother, who has noticed a searching nystagmus. The baby was born by caesarean section. Normal pregnancy. Only child. Much inquiry by mother has revealed that apparently there were two albino individuals on her side of the family. Six generations back in the maternal grandfather line and four generations back in the maternal grandmother line. There is no accurate history of these cases nor any living relative that saw them, so nothing is known as to degree of albinism. The mother of this patient shows average pigment and the father is quite dark. There are no other congenital defects. The baby is large and has been very healthy. The hair is snow white and the skin is without color.

EXTERNAL AND INTERNAL EXAMINATION

The ocular adnexa seems normal in every way. There appears to be no structural defects except the lack of pigment. The pupils respond to light. The supporting structure of the iris can easily be seen as the iris is almost transparent. (Figure 1.) The sclera is also quite translucent when the globe is transilluminated. Gross versions seem to be complete. There is a marked nystagmus of both eyes. The amplitude of the nystagmoid movements is rather large. The child has an obvious aversion to light. The media appear perfectly clear. Because of the nystagmus, intolerance to light and age of patient it is impossible to make a careful study of the fundi. There appears to be a marked lack of pigment. The choroidal vessels are visible. Unfortunately it was impossible to make a study of the macular areas.

REFRACTION

For obvious reasons only a very very rough retinoscopy could be performed with this child. There is apparently no marked refractive error at this time, if anything, there is a tendency toward hypermetropia.

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It is impossible to determine the acuity of vision but it is evident that the child does see with a certain amount of resolving power. There

Fig. 1

Fig. 2

is some indication that his visual behavior is somewhat less than that mentioned by Gesell (*Vision, Its Development in Infant and Child*, page 193) for the 12 weeks' level.

DIAGNOSIS AND TREATMENT

Edmunds in *Archives of Ophthalmology*, December, 1949, states: "Albinism is characterized by pigmentless hair, skin and eyes, and by ocular defects. Ametropia, astigmatism, nystagmus, photophobia and amblyopia are almost invariably all present." While the refractive defects cannot yet be measured accurately in this case it is apparent, using the above criteria, that this is a case of complete albinism. It was felt that in treatment two things should be attempted: (1) To improve fixation and (2) To cut out as much extraneous light as possible. I felt that pinhole spectacles would best accomplish these two objectives.

This case was discussed with Dr. C. L. Weston, ophthalmologist, of Macomb, Illinois, and he concurred in my plan of treatment. A special pair of spectacles were made with opaque discs and opaque side shields. The Shuron Tiny Tot frame was used. A 3 mm. pinhole for each eye was made to correspond to the p.d. of 50 mm. Special temples ending in loops were made so that an elastic band could be used around the head. (Figure 2.)

PROGRESS REPORT

The child wore the spectacles remarkably well. The parents were convinced that the child was receiving the proper treatment but the

grandparents and neighbors had much to say about making the child wear such a device.

The grandfather was finally convinced when, while wearing the spectacles, the child held out his arms to him. The child was seen frequently for adjustment and to observe progress. The device was very satisfactory except for perspiring around the eyes in hot weather.

SUBSEQUENT EXAMINATION

The nystagmus is less after six months from initial examination and vision seems improved, so it was decided to try absorption lenses. Since nothing accurate could be determined about the refraction, plano No. 4 crooks lenses were used. This was made up in an A. O. Cub frame with the regular comfort cable temples.

Again the child wore the glasses very well, always out of doors and most of the time inside. He will hardly open his eyes outside without the glasses.

Nine months later the patient is apparently doing very well. Nystagmus is still present but the amplitude is definitely less. Vision is improving, for example, he readily noticed a small paper clip on the desk and picked it up. He seems to enjoy playing with all sorts of toys. He does hold toys very close to his face when he studies detail.

SUMMARY

A child with complete albinism first seen at four and one-half months. Typical picture of absence of pigment, nystagmus, reduced acuity and photophobia. In Edmunds' series of 16 subjects the average corrected acuity was 20/200. According to Pearson, Nettleship and Usher, refractive errors are found more frequently in albinos than in persons with normally pigmented eyes.

It will be interesting to follow this case and to do everything possible in a palliative way to keep the child from being too much of a visual invalid.

Edmunds reports on the use of special contact lenses for albinos. These lenses have an opaque sclera and iris. In his series of cases most of them showed marked improvement in vision and comfort with such a contact lens.

As this would appear to be the best solution in such a case, this has been explained to the parents so that they may look forward to such treatment for their child.

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SIX YEAR PROFESSIONAL COURSES FOR OPTOMETRY

As a result of the recommendations contained in the annual report of its Council of Education and Professional Guidance, the A. O. A. House of Delegates at its recent meeting in New Orleans resolved unanimously that the *Doctor of Optometry* degree is the desirable degree for the practitioner of optometry. The delegates further resolved that the A. O. A. should exert its efforts towards having all colleges of optometry confer the doctorate degree. The intention of the A. O. A. in adopting these resolutions is to help and encourage the educators in optometry

to bring about this desirable goal. Today, six of the 10 colleges of optometry in the United States confer the doctorate degree. Forces outside of optometry and beyond the faculties concerned dictate the action of the remaining four colleges. These forces could, no doubt, be influenced favorably by appropriate presentation of the facts of optometric education stressing the continuing improvements and progress in the total educational standards of our colleges.

At the present time, the minimum standards under which all our colleges of optometry operate are either two years of pre-optometry and three years of professional work or one year of pre-optometry and four years of professional work. On these bases, all colleges require at least a five year program beyond secondary school. In fact, many optometry students acquire bachelor degrees before entering upon the study of optometry. Although a complete study of the total higher education of optometry students has not been made, it is estimated that the average number of years of higher education obtained by recent graduates in optometry exceeds six years.

It would seem that the first step in the process of establishing the right to the doctorate degree for all graduates in optometry would be the adoption of a full four year professional program by all the colleges of optometry. This would be in keeping with the professional programs of other health professions; namely: medicine, dentistry, veterinary medicine, chiropody and osteopathy. In addition to the four year professional curriculum, this program should include one year of pre-optometric training on the college level, as it does today in several of our optometric colleges. An increase to two years of pre-optometric college work should be the next step as soon as conditions make it practicable. We may look forward later, perhaps, to a three and even a four-year pre-optometric college requirement as times and future circumstances permit!

Educators in optometry agree in general that a six year program of post-secondary school education is most desirable for the good of the optometrist and the profession. This should include two years of pre-optometry and four years of professional work. A four year professional curriculum, free of any fundamental courses that can be included in the collegiate program, allows for a better balanced optometry course with a more thorough training in clinical practice than do the present curricula of our colleges.

The "doctor" title is always associated with the practitioner of any of the health professions in America. Hence, the doctorate degree

is most essential to the members of our profession. The lay public is not concerned with the number of years of higher education which a particular practitioner has devoted to earning his title of "doctor." But, as applied to the health professions, the present day doctorate degree is now fully accepted in academic circles only when based upon two or more years of undergraduate collegiate work followed by four years of professional training. Full professional stature can come to our profession only after it has been fully earned. It can be earned by the presentation of an educational program which matches the program of other health professions.

The A. O. A. is to be commended for its stand. Educators in optometry who have been working for the privilege of conferring a Doctor of Optometry degree will welcome this support.

CAREL C. KOCH.

CURRENT COMMENTS

Virginia Huck
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department; such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

ACADEMY HONORS BENEDICT

The American Academy of Optometry announces it is awarding its fifth Honorary Life Fellowship to Dr. William L. Benedict, Secretary of the American Academy of Ophthalmology and Otolaryngology and Editor of the TRANSACTIONS OF THE AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY, Rochester, Minnesota. Academy President Harold Simmerman, Woodbury, New Jersey, will present the award to Dr. Benedict at the coming annual meeting of the Academy at the Hotel New Yorker, New York City, next December.

The Academy voted to make Dr. Benedict an Honorary Life member in recognition of his many important contributions to the field of ophthalmic science, and for his efforts to promote harmonious relationships between those working in the field of visual care. Until his recent retirement from practice, Dr. Benedict served as the director of the Mayo Clinic's Section on Ophthalmology in addition to his work with the A. A. O. O.

PROGRAM SHAPING FOR COMING ACADEMY MEETING

With the annual meeting of the Academy less than four months

away, Dr. Meredith W. Morgan, chairman of the program and papers committee, urges any speaker who has not sent his paper to him, to do so immediately. Dr. Morgan reports the coming program of papers is shaping up to the usual excellence of past Academy meetings. He will make an announcement of the titles and lecturers in a coming issue of the Journal.

CHICAGO COLLEGE LOSES PRESIDENT

Dr. Reuben Seid, 53, President of the Chicago College of Optometry, died Monday, July 9, 1951, at his residence in Chicago, Illinois, after a brief illness.

A native of Chicago, Dr. Seid studied medicine and received his degree at the University of Illinois in 1926. He practiced as a physician in Chicago and in 1937 was instrumental in founding the Monroe College of Optometry, which later became the Chicago College of Optometry. Dr. Seid is survived by his widow, Anne, and two sons, Barre and Richard.

CAMPUS NEWS

Opening of Fall classes will find major changes in faculty at some of our optometric colleges. Dr. Richard Feinberg becomes dean of Northern Illinois College of Optometry on September 1, after serving the Pacific University College of Optometry in the same capacity for the past three years. Also new on N. I. C. O.'s staff will be Dr. Marguerite Thoma Eberl of Milwaukee, specialist in the visual problems of school children, and Dr. Peter C. Kronfeld, Chicago, ophthalmologist. Dr. Eberl will lecture weekly to senior optometry students; Dr. Kronfeld will serve as chief consultant in the ocular pathology department.

Dr. Mathew Alpern has joined the faculty of the College of Optometry, Pacific University. Prior to this new assignment, he served on the faculty of the School of Optometry, The Ohio State University.

Chicago College of Optometry announces a grant of $300.00 to Dr. Ernest Ball (M. A., C. C. O., June, 1951) to aid him in research at the college under the faculty research director. The grant will be used to complete investigations for a paper on "A Study in Consensual Accommodation."

Rutgers University is sponsoring an occupational vision conference November 1 and 2 in Atlantic City. At the meeting, attention will be focused upon new concepts in lighting, functional color for better human efficiency and safety, occupational vision hazards, occupational eye injuries, relation of visual efficiency to motion and work, and

establishing a workable visual program. Leading industrial vision specialists are scheduled to speak: Commander R. R. Sullivan, Bureau of Medicine and Surgery, United States Navy; R. S. Krueger, Director, Industrial Service of the National Society for the Prevention of Blindness; Sylvester Guth, Director, Lighting Research, General Electric Company; R. J. O'Shea, Director, Industrial Vision Program, Maryland Society for the Prevention of Blindness, as well as other industrial leaders.

The conference will be the cooperative effort of the University Extension Division, several engineering societies, National Society for the Prevention of Blindness and various New Jersey State departments and optometric groups concerned with the conservation of vision.

ACADEMY PUBLISHES WALLS' MONOGRAPH

Dr. Gordon L. Walls' three-part paper, "The Problem of Visual Direction," which ran in the February, March and April, 1951, issues of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY, is now available in reprint form. This Academy reprint is Monograph 117, runs 101 pages plus cover, and sells at $1.00. When ordering, please address the American Academy of Optometry, 1502 Foshay Tower, Minneapolis 2, Minnesota, and order by monograph number. Make out all checks and money orders to the Academy.

DEFERMENT PROGRAM FOR COLLEGE STUDENTS

Editor Carel Koch brought back the following report from his July monthly meeting with General Hershey's Educational Advisory Committee to Selective Service:

Present government plans are to keep our military forces at the current level (3,200,000) with possible substantial expansion if world conditions require it.

The problem of deferment for graduate students working on Ph.D.'s was reviewed and recommendations made for revision of present policies—final decisions on this to be announced later through proper channels.

A tabulation of the results of the first Selective Service College Qualification Test, held on May 26, 1951, has been furnished the Director of Selective Service by the Educational Testing Service of Princeton, New Jersey. A total of 165,000 registrants had taken the test on that date. Of this number, 42,500 were freshmen; 53,000 sophomores; 44,000 juniors; 18,500 seniors; 7,000 graduate students. A total of 340,000 students took the four tests.

Fifty-three per cent of the freshmen, 64 per cent of the sophomores, 72 per cent of the juniors, and 77 per cent of the seniors scored 70 or better.

The percentages of male college students who took the May 26 test varied between geographical areas. There were as follows: North East, 18 per cent; Mid Atlantic, 15 per cent; Eastern North Central, 12 per cent; Western North Central, nine per cent; South Atlantic, eight per cent; Eastern South Central, seven per cent; Western South Central, six per cent; Mountain, seven per cent; Pacific, eight per cent; Territories, three per cent; over-all ratio, 11 per cent. Samples indicated that approximately 40 per cent of the students in the lower portion of their classes received a score of 70 or better, and that 75 per cent in the upper portion of their classes received a score of 70 or better. It was emphasized that complete tabulations might change the figures.

The Scientific Advisory Committee, composed of noted educators and health workers, was appointed by Major General Lewis B. Hershey, Director of Selective Service, after passage of the Selective Service Act to make recommendations on a Student Classification Plan. The Committee is composed of six Subcommittees representing agricultural and biological sciences, engineering sciences, humanities, healing arts, physical sciences and social sciences.

Dr. M. H. Trytten, Director of the Office of Scientific Personnel, National Research Council, is head of the Committee. Dr. Carel C. Koch represents optometry on the healing arts committee.

Along this line, we'd like to comment that students in the healing arts professional schools receive most favorable military deferment treatment under new Selective Service regulations. In some important respects students of medicine, dentistry, veterinary medicine, optometry and osteopathy are given scholastic deferment advantages not enjoyed to quite the same extent by college students in non-health sciences. The reason is the shortage of health workers. The advantage, if it can be called that, also brings added responsibility to the deans of our optometric colleges. Students who are taking optometry merely to "dodge-the-draft" should be quickly weeded out in the orthodox manner by the faculty, and only those students whose efforts and interests in the subject are evident by actions and grades should be permitted to continue their optometric education during the period of this military crisis.

A. A. A. S. MEETING IN PHILADELPHIA

The American Association for the Advancement of Science has announced its preliminary plans for the coming 118th annual meeting which will be held next December in Philadelphia. All of the Association's 18 sections and about 45 participating societies will hold educational sessions, and as in the past, the annual Exposition will total about 150 booths, filling the arena of Philadelphia's Convention Hall. Coupons for hotel reservations are now running in *Science* and *The Scientific Monthly*, publications of the A. A. A. S.

NATIONAL BOARD OF EXAMINERS IN OPTOMETRY APPOINTED

Appointed members of the recently created National Board of Examiners in Optometry are Dr. Rudolph H. Ehrenberg, Chairman, Granite Falls, Minnesota; Dr. N. E. Abrahamsen, Cleveland, Ohio; Dr. Richard Feinberg, newly appointed dean, Northern Illinois College of Optometry, Chicago, Illinois; Dr. Harold M. Fisher, member of faculty, School of Optometry, Columbia University, New York City; Dr. W. Goyer, Hattiesburg, Mississippi; Dr. H. W. Hofstetter, Dean, Los Angeles College of Optometry, Los Angeles, California, and Dr. John R. Uglum, Mitchell, South Dakota. These appointments were announced by the International Association of State Boards of Examiners in Optometry.

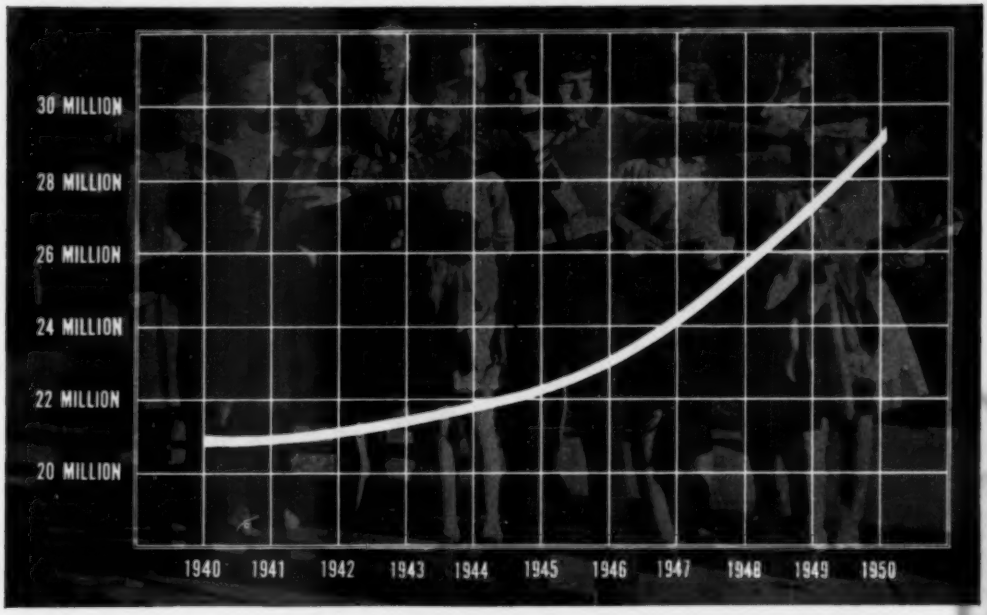
JOURNAL STAFFER WINS THETA SIG AWARD

The writer of this department enjoyed a fine trip to Kansas City last month where she received the 1951 annual research award of Theta Sigma Phi, national sorority for women in journalism. This $500.00 award will be of considerable help in working for a Master's Degree in Journalism. Optometry received a good nationwide press in this connection. The writer managed to get out of Kansas City on the last train before the floods.

NEWS BRIEFS

Missouri optometrists Dr. W. R. Henry, Warrensburg, and Dr. J. R. Brockhorst, St. Charles, have been appointed to the Missouri Professional Advisory Committee of the National Society for the Prevention of Blindness, according to Dr. Franklin M. Foote, National Executive Director of the Society. Dr. Henry is president of the Missouri Optometric Association; Dr. Brockhorst, Secretary of the Missouri State Board of Optometry. . . . Recognizing the fact that there has been nearly a 40 per cent increase in the number of school children under 10, during the past 10 years, Soft-Lite Lens Company has prepared a brochure entitled, "Send the Whole Child to School in September," directed to parents, teachers and doctors. . . . New officers of the Canadian Association of Optometrists elected at the recent all-Canada Congress: Mr. Harry S. Nowlan, president, and Mr. F. M. Farr, secretary. Mr. Nowlan has been practicing optometry since 1918 in Winnipeg, and has served the Association as vice president for two terms. Mr. Farr, a Montreal practitioner, takes the office left vacant by the death of Mr. Edward Bind last year. . . . Dr. T. R. Murroughs, Director of the Department of Strabismus Research, Chicago College of Optometry, resigned effective September 1. His work on this important subject will probably be carried on in the future at the Northern Illinois College of Optometry.

FACTS OF LITE in the classroom



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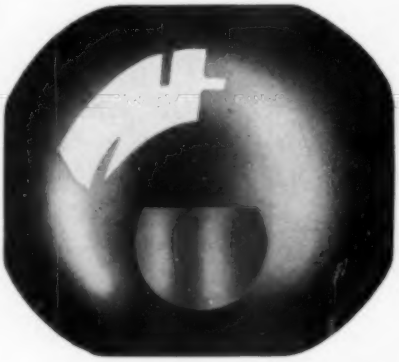

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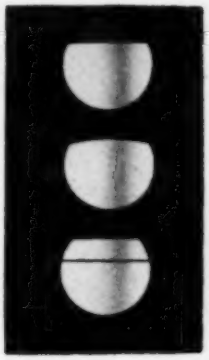

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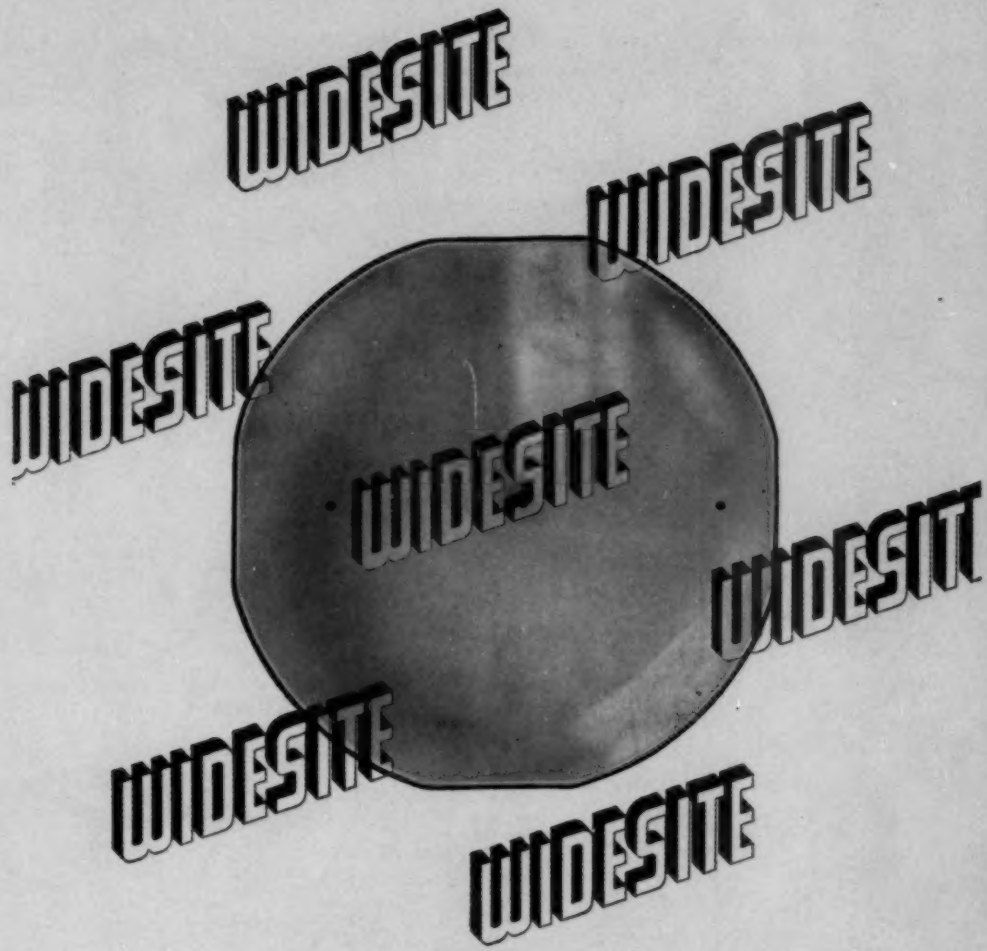

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